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TECHNOLOGY and CULTURE

The International Quarterly of the Society for the History of Technology

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In Memoriam

Dr. William Fielding Ogburn, President of the Society for the History of Technology, died suddenly on April 27, 1959. One of the guiding spirits in the formation of our organization, Dr. Ogburn pioneered in the study of the relations of technology and social change, and his death is a great loss to the entire world of scholarship as well as to our Society.

An appreciation of William Fielding Ogburn, by Otis Dudley Duncan, appears on page 94 of this issue.

At the Start[1]

MELVIN KRANZBERG*

I

"FRAGMENTATION!" was the offhand critical judgment of a distinguished historian when he first heard of the formation of the Society for the History of Technology. Like most scholars, he rightly deplores the modern tendency to "learn more and more about less and less," and he was delighted when he realized that the nature of our subject matter requires an "interlacing" of disciplines rather than a further "fragmentation" of knowledge.

Indeed, the development of technology and its relations with society and culture are such broad subjects that our new Society and its publication must be interdisciplinary in scope. We are concerned not only with the history of technological devices and processes, but also with the relations of technology to science, politics, social change, economics, and the arts and humanities. For the first time an effort is being made to bring together the engineer, the scientist, the industrialist, the social scientist, and the humanist to promote the study and interpretation of developments which are of mutual interest and concern.

The title of our publication, *Technology and Culture*, was not lightly chosen. It reveals the breadth of our definition of culture and indicates our awareness of the complex and intricate interrelationships of all aspects of technology. We use "culture" in the broad anthropological sense defined by Edward B. Tylor almost a century ago: "Culture is that complex whole which includes knowledge, belief, art, morals, laws, custom, and any other capabilities and habits acquired by man as a member of society." Technology itself is one of the most distinctive and significant of

* Dr. Kranzberg, Professor of History at Case Institute of Technology, was chairman of the committee which organized the Society for the History of Technology.

man's capabilities, and it is essential that we learn how it developed in order to analyze its relations with the other elements of culture.

The interdisciplinary nature of our subject matter inevitably dictates the form and scope of our journal. It accounts also for our audience. We intend to appeal to the engineer, to the social scientist, to the scientist, to the humanist—to the academic scholar as well as to the intelligent layman—for our subject is of importance to all these. The engineer should realize that his professional activities impinge upon all elements of our culture—that a bridge or telephone fulfills economic and social needs and possesses esthetic and cultural values as well as technological elements. Similarly, the social scientists and the humanists should be aware of technological influences on society and the individual, but they cannot understand these influences unless they have some knowledge of how technical devices came into being and how they function.

Anyone who is at all interested in understanding the past, in learning how the present got to be the way it is, or in speculating about the future—and this would include every thinking man—must be concerned with the development of technology and its relation with society and culture.

The justification, then, for our Society and for this publication is our subject matter: technology. There is little point in belaboring the obvious importance of technology: the use of tools, together with the development of moral sensibility—and the interrelation between changing moralities and changing technologies is by no means clear—has enabled man to advance from an ape-like creature through the Stone and Bronze Ages eventually into an industrial society whose objects we see all around us and which conditions our daily lives. Furthermore, our hopes and fears for the future of mankind are largely bound up with technology.

II

Despite this tremendous and acknowledged significance of technology, it is curious that in twentieth century United States, one of the most technologically minded of all nations in history, there has been no organized group nor scholarly periodical specifically devoted to the study of technology as a human activity and of its relation to other concerns.

How can we account for this neglect? It has its roots deep in

the past, and we can trace it as far back as Plato's distinction between brain and hand, i. e., the notion that thinking is man's highest activity whereas manual labor lacks dignity and is confined to lower class individuals of inferior capacity. This Platonic notion corresponded to the social system of antiquity when work was left largely to the slaves; Aristotle merely expressed a characteristic ancient attitude when he denied slaves the rational qualities of man, thereby classifying them as inferior beings.

This Platonic dualism of brain and hand persisted through the Middle Ages, even though the monks gladly performed manual labor as a means of extolling God.[2] We owe many great technological advances to these cloistered brethren, who believed that "to work is to pray" (*laborare est orare*). But the word "servile," from the same root as "serf," betrays the low esteem in which manual work was held by the medieval aristocracy.

As the bourgeois industrial society began coming into existence in modern times, there were indications that the Platonic aristocratic dualism was beginning to wane. The self-made man who had started as a menial laborer and worked his way up the ladder of success came to be a respected member of the community, while the aristocrat who disdained to soil his hands by honest toil became a target of social criticism. This revolution in social attitudes went farthest in America; the development of social democracy—caused by the influence of the frontier, the disciples of Frederick Jackson Turner would say—elevated the role of the worker. Indeed, the American myth: from log cabin to the White House, fostered the feeling that manual labor was not a thing to be despised but rather an indispensable prerequisite for the great American dream of success. What a far cry from the ancient attitude toward work!

As the public attitude toward work changed so did the prevalent attitude toward technology. The magnificent achievements of the Industrial Revolution in supplying man's material wants and creature comforts served to develop an awareness of the role of technology in civilization.

Paradoxically, the widespread use and appreciation of the products of technology did not result in greater esteem for the engineer, the man responsible for this progress. Despite the fact that our civilization has become overwhelmingly dependent on technology, despite the fact that the products of technological development

are used and admired, despite the fact that engineering has become an increasingly complex field requiring specialized education, the engineer, even today, has not received adequate recognition for his training and for his contribution to society. The constant efforts of the American Society for Engineering Education and the Engineers Council for Professional Development to elevate the professional status of the engineer attest to this.

The reason for this paradox is not hard to find: the American success story glorified the man who *began* his career by working with his hands; his success lay in progressing *beyond* that stage so that he no longer need perform tasks requiring muscle or technical skills. Thus the man whose lifetime work was designing and developing tools for work or using these tools to create things—in other words, the engineer—did not find his status elevated proportionally to the high opinion held of his products by the public. In fact, the word "engineer" itself was, and still continues to be, loosely applied to both the technologist who deals with highly complex nuclear devices and the man who drives a locomotive, to the designer and builder of intricate machine tools and computing devices as well as to the plumber who fixes a leaky faucet or unplugs a sewer and labels himself a "sanitary engineer." All too often technology was associated with mere "gadgetry." Although high above the level of the unskilled manual laborer, the modern engineer still suffers from the anachronistic attitude toward the men who make and work with tools, which is part of our heritage of social attitudes from classical antiquity.

For a time the academic world lagged behind popular opinion in its appreciation and awareness of the role of technology. Until relatively recent times the world of scholarship had concentrated its attention upon the humanities, particularly the classics. Influenced by Plato's separation of "ideas" from "things" and his insistence that true virtue lay in knowledge of the "ideas," the humanities tended to denigrate technology as being "materialistic." Nor is it surprising that devotees of the intellectual life should have continued to adhere to Plato's elevation of things of the mind over the labors of the hand, especially when the world about them was increasingly devoting itself to material concerns, neglecting both the spiritual and intellectual aspects of life.

Under these circumstances, the very successes of technology

probably militated against the study of its background and development, even when the "cult of work" developed during the nineteenth century. Humanistic scholars of the Victorian era sometimes looked with horror upon the rising industrial society which they believed destructive of the beauty of life and of nature. Ostrich-like, they tried to conjure away industrialism by burying their heads in the sandy desert of more conventional scholarship. The ivory-towered life of contemplation, stressed by ancient philosophers, seemed incompatible with the study of contemporary changes in society, especially those concerned with the feared, and often hated, technology.

Even when the scholars and educational institutions could no longer ignore technology, and even after the foundation of engineering colleges devoted to training in this field, the study of technological growth languished. Why bother with the past? Why investigate what has already been superseded? The study of political or intellectual history admitted no such questions; past politics, past philosophy, past literature—all were believed to teach valuable lessons, as well as having intrinsic value. No such claims were made for the history of technology; not only was technology itself viewed as an inferior subject, but the study of its past was considered irrelevant. Besides, technological advances occurred so rapidly that both scholar and student were hard-pressed to keep up with the newest developments, let alone peer into the lessons of the past.

The history of science suffered under much the same disability; both scientists and the public were too concerned with the "latest" scientific discoveries to devote any time to the past. Only the constant efforts of a small group of scholars, particularly those of the late George Sarton, succeeded in making the history of science into a reputable scholarly discipline, and only recently has the history of science achieved some measure of academic acceptance. In this respect, the history of technology has lagged several decades behind the history of science.

III

The neglect of the study of technology was of course not absolute, and the findings of modern scholarship were eventually to make the scholarly world take a keen interest in the role of tech-

nology. Modern physiology, psychology, evolutionary biology, and anthropology—all combined to make the scholarly world aware that *homo sapiens* could not be distinguished from *homo faber*. Indeed, it gradually was realized that man could not have become a thinker had he not at the same time been a maker.

As the fallacious Platonic distinction of brain and hand lost support, the study of man's technological creativity became as respectable as the study of man's artistic or literary creativity. Many scholars advanced the proposition that man's creative instincts were of the same provenance, no matter in what fields these were exercised. In other words, scholarship finally began to absorb the implications of human physiology and human psychology, just as the public had already assimilated the implications of social democracy with its emphasis upon the dignity of work.

Individual scholars, organizations, and periodicals began to concern themselves with technological studies. Scientific journals and societies, including those dealing with the history and philosophy of science, produced programs and invaluable articles on certain aspects of technology; engineering periodicals published material on the history of their respective fields; and journals in the social sciences and the humanities frequently contained articles dealing with the relations between their specialized disciplines and technology.

Nevertheless, all this worthwhile activity scarcely constituted a major attempt to explore all facets of technology. The scientific journals did not have as their main purpose the assessment of the role of technology in the past, present, and future; hence there remained a wide gap in our knowledge of the relationships between man's attempts to understand nature and his efforts to control it, between his questionings of nature and his making and doing things. The readers of engineering publications tended to be more interested in blueprints than in historical insight, and the sporadic contributions on the history of technology in engineering journals did not represent any systematic attempt to make clear the relations between engineering and other aspects of culture. Similarly, the periodicals of the social scientists and humanists were more properly concerned with sociological data, with anthropological interpretations, with economic problems, with philo-

sophical speculations, or with esthetic considerations than with technological elements.

This failure to study thoroughly the development of technology and its relations with society and culture was not due to indifference on the part of the scholars—they were well aware of its significance—but rather to the lack of personnel qualified to deal with these studies. Serious historical scholars, with but a few notable exceptions, shied away from the field because of a feeling that they lacked the requisite technical knowledge to treat it properly. It was largely left to the engineers to write technological history, and despite the fact that many engineers wrote gracefully, others found it easier to express themselves in blueprints, or in steel and concrete, than in words. Even when an engineer was articulate, his efforts would frequent reflect the fact that just as few historians are learned in technology, few engineers are skilled in the rigors of historical research. The same considerations applied to the other social sciences and humanistic disciplines: lack of an adequate technical background often made scholars in those fields neglect very important relationships between social and cultural developments and technological change. However, the contributions of these scholars had the merits of pointing out that technology could not be studied in a vacuum and that its history must also comprise the social and cultural elements in civilization.

Hence there remained an obstacle to the study of technology and its role in society. This obstacle was no longer the indifference of scholars nurtured on the Platonic dualism of ideas and things, of brain and hand; rather, it was the lack of basic knowledge regarding the course of technological development itself.

Anthropologists, sociologists, economists, historians, humanists, scientists—all those who were concerned with the relations of technology with other elements of society and culture—were forced to the realization that their studies had no solid foundation because of the lack of a substantive knowledge of technological development. Not enough was known about the "hardware"—the actual devices and techniques which constituted technology. Valid generalizations could not be made regarding the esthetic impact of technology, its relations with processes of social change, its effect upon industrial organization, its role in the growth and decline of civilization, or regarding any of a number

of other fields of investigation, without accurate and detailed knowledge of the history of technology as such.

This consciousness as to the deficiency of substantive data accounts in large measure for the welcome accorded the five-volume *A History of Technology*, edited by Charles Singer, E. J. Holmyard, A. R. Hall, and Trevor I. Williams. This encyclopedic work pioneers in a field where individual scholars, such as R. J. Forbes, Franz Maria Feldhaus, Joseph Needham, have already shown the way. *A History of Technology* represents a beginning, a stimulus to further research, rather than a culmination of scholarly efforts. It provides a necessary foundation upon which scholars can build, or, to change the metaphor, it is similar to the first efforts of the cartographers of the fifteenth century shortly after the voyages of Columbus and his immediate successors: the existence of a new world is known, but there still remains much *terra incognita*; and much further exploration is necessary to fill in the exact outlines and to explore the interiors in depth.

A systematic and continuing study of the history of technology as such is necessary, and that is one of the reasons for the founding of the Society for the History of Technology and for the publication of this journal. To be sure, ours is not the first nor the only journal in this particular field. The British Newcomen Society has long and successfully encouraged the history of technology, but the *Transactions* of the Newcomen Society are running several years behind. The other European journals in this field (for example, the *Technikgeschichte* of the Verein Deutscher Ingenieure, which published many outstanding articles) have, for one reason or another, suspended publication. *Technology and Culture*, therefore, will be an international quarterly, to serve the needs of scholars in America and throughout the world.

Despite the great merits of the Singer volumes and other works, these publications do not obviate the necessity for further research in the history of technology. Instead, they encourage it. What is more, they increase the need and desirability of studying the relations of technology with other elements of society and culture. *A History of Technology*, for example, deals with technology only within the framework of its own subject matter, as if it were insulated from the rest of society. Such a treatment derives inevitably from the definition of technology as "how things are

commonly done or made" and "what things are done and made."[3] But many other questions immediately come to mind: *Why* are things done and made as they are? What effects have these methods and things upon other areas of human activity? How have other elements in society and culture affected how, what, and why things are done or made? The five volumes of *A History of Technology* codify the present state of scholarship, but they do not answer these further questions.

Yet we cannot hope to understand our civilization, or even technology itself, unless we grasp the manifold relations between technology and society. In other words, an *interdisciplinary* approach is needed if we are properly to study the history of technology. This multi-faceted approach accounts for the unique character of our organization and this publication.

No existing American journal or organization gives primacy to the study of the history of technology; no existing journal or organization in the Western world gives primacy to the study of the relations of technology with society and culture. It is these serious gaps in organized scholarship which the Society for the History of Technology and its journal, *Technology and Culture*, attempt to fill.

IV

To accomplish what we regard as our threefold educational mission, namely, to promote the scholarly study of the history of technology, to show the relations between technology and other elements of culture, and to make these elements of knowledge available and comprehensible to the educated citizen, *Technology and Culture* will publish general articles dealing with the relations of technology with society and culture as well as more specialized articles on the history of technological processes and devices. We hope to appeal to both scholar and non-academican, even though we realize that our insistence upon rigorous standards of scholarship may prevent ours from ever becoming a popular magazine of mass circulation.

The first issue of *Technology and Culture* provides a by-no-means exhaustive sample of the wide range of interests comprehended under our title. Our first group of articles might be considered as an introduction to the study of technology and may be

described as state-of-the-field articles; for they are written by well-known authorities from various disciplines who tell what has thus far been accomplished in the study of the relations of technology with their respective fields, define the chief problems, and point out avenues of research which might lead to fruitful results in the future.

The second group plunges into the substantive content of the study of technology, and here again it is only a sampling of the periods of history and the areas of technological development with which we are concerned. Then we have those indispensable aids to scholarly research: book reviews. Bibliographies will appear in subsequent issues.

In brief, this opening number attempts to define the role of the study of technology, to note the point which this study has reached thus far, and to indicate where it may lead in the future. It also provides case studies of specific developments in technology and their relations to other aspects of human life, and it offers tools for further investigation.

As might be expected of an organization with the word "history" in its title, we are mindful of our own professional past, despite its brevity. Hence, the final section of this first issue provides a short history of our Society. Our object is to promote the study of the development of technology and its relations with society and culture. One measure of our success in achieving this goal will be the reception accorded, by professional and layman alike, to this journal: *Technology and Culture.*

REFERENCES

[1] Much of the material of this article derives from a meeting of the Advisory Committee for Technology and Society, held at Case Institute of Technology on January 30-31, 1958, which led to the formation of the Society for the History of Technology. Participants in this conference, either by correspondence or in person, were Russell L. Ackoff, Carl W. Condit, George A. Gullette, Morrell Heald, Thomas P. Hughes, Melvin Kranzberg, Edward Lurie, Hugo A. Meier, Robert P. Multhauf, Lewis Mumford, William Fielding Ogburn, Stanley Pargellis, John B. Rae, Thomas M. Smith, Lynn White, Jr.

[2] See Lynn White, Jr., "Dynamo and Virgin Reconsidered," *The American Scholar*, XXVII, No. 2 (Spring, 1958), 183-194.

[3] Charles Singer, E. J. Holmyard, A. R. Hall, and T. I. Williams, *A History of Technology* (5 vols., New York and London, 1954-8), I, vii.

The Hardware of Culture

ROGER BURLINGAME*

I

No person who has followed the trends in historical writing can fail to be impressed by the revolution that has taken place in the last quarter century in the treatment and acceptance of the technological story. The record of the technics of the past has come alive. We may read today not merely of machines and processes, of architecture and engineering in their separate existence at various stages of civilization, but of their bearing upon one another and even upon social evolution. Today it is occasionally possible to look down a vista into a remote past and see such evolution as a whole with its parts in just perspective. In this vista we see not only the struggle of mankind toward the abstractions of liberty or political and economic order but the physical factors which were often causal. To put it in modern jargon we see in this vista the " hardware of culture."

I say it is " occasionally possible " to see this continuity. There is still a long way to go. The task of the historian who would integrate social and technological history was, when it was first attempted, Herculean. He had to search in the darkest corners for his primary technological sources. Often the documents he needed were manuscripts or books in foreign languages. He found some of his most useful records in the encyclopedias, particularly that of Diderot and d'Alembert, in which the processes and machines of the past are minutely described and beautifully illustrated. If he was concerned with ancient cultures, he must study the great works of Pliny, Vitruvius and Lucretius among others; or, if he was writing of the Renaissance, he must be satisfied with the

* Roger Burlingame has written many books and articles on the development of American technology. His autobiography, *I Have Known Many Worlds*, has recently been published.

scattered records of the designs of Leonardo or dig out such works as Agricola's *De Re Metallica*—not adequately translated into English until 1912—or Jacques Besson's *Theatre des Instruments*, Biringuccio's *De La Pirotechnia*, not translated until 1925 and then only into German, or the fantastic record of sixteenth century invention by Jacobus de Strada published in Germany in 1617 and containing engravings of devices of which Rube Goldberg would be proud.

Finally, if modern "hardware" interested him, there were such classics as Farey's *Treatise on the Steam Engine*, biographies of the engineers by Samuel Smiles (in which one may find human beings among the machines) and Oliver Evans' *The Young Millwright and Miller's Guide* and *The Young Steam Engineer's Guide*, to name a few.

Yet most of these books stood on dusty shelves known only to knowledgeable librarians. They were special. The historian must work his way from one watertight compartment to another to achieve anything resembling a survey of technological history, let alone a solved picture puzzle with the technological pieces fitted into a cultural pattern. And, for many years, the general surveys—histories, for example, of mechanical inventions—were for the most part spotty, dull, pedestrian, and often grossly inaccurate. Some were frankly juvenile, as if such matters were hardly fit for adult reading.

Somewhere along in the second decade of the twentieth century, the change began. Since 1910, many of the classics of architectural and engineering record—until then submerged in a dead language or lost except to industrious scholars in rare-book rooms—have been brought alive. The revolution was greatly stimulated by the stepped-up activities of archeologists who unearthed artifacts that altered our concepts of physical ways of life in ancient civilizations. These have inspired scholars to search the documents and books for corroboration or new evidence. The books were translated into readable English as well as other modern languages and abundantly annotated with the results of spade work by explorers in related fields.

Catching on in this movement as it gained momentum were professors of engineering and even an occasional practical engineer. No less an expert than Herbert Hoover in collaboration with his

wife, Lou Henry Hoover, translated Agricola's valuable and exhaustive book on mining, *De Re Metallica*, from the original Latin folio of 1556.[1] This book is remarkable for its engraved illustrations, done with a care for accuracy of detail uncommon in that period. In the next year, the classic on the water supply of the city of Rome, written in the first century A. D. by Frontinus, was brought out in translation in New York. Then came the Oxford edition of Roger Bacon's *Essays*—including that in which Bacon, in the thirteenth century, explained the use of explosives in rock blasting—carefully edited and annotated by Andrew G. Little.[2] In the 1930's, the publication in English of the assembled notebooks of Leonardo da Vinci,[3] including many thereto unknown, turned public interest which for some four centuries had centered upon the artistic genius of this many-sided artist to his extraordinary power as an inventor and engineer. While much of Leonardo's vision in these directions remained for centuries on paper before the times and collateral knowledge could turn it into " hardware," the resurgence of interest in the forgotten aspects of this artist had a preponderant influence on technological historians.

In the 1930's, also, Vitruvius was newly brought to life in a two-volume edition,[4] and a significant event in the new appeal of technological history to practical American mining engineers was the publication in English by the American Institute of Mining and Metallurgical Engineers of the *Pirotechnia* of Vannocio Biringuccio.[5]

Meanwhile, as the primary sources became more and more accessible, there came a flood of interpretive books by eager students of technological history. There was searching investigation of the engineering and architecture of Egypt, Greece, Babylon, and Rome by such writers as William Lane, James Baikie, William Dinsmoor, and, of course, Breasted and Sarton. New researches showed that the Dark Ages were by no means so dark as had been supposed. There were two books by Louis F. Salzman: *English Industries of the Middle Ages* and *Building in England Down to 1540*,[6] and there was a scholarly piece by Lynn White on " Technology and Invention in the Middle Ages." [7]

Then there were highly readable books about the origins and beginnings of the Industrial Revolution. Myths about the inventors of textile machinery in eighteenth century England were aired

and renovated; the complete history of the steam engine took shape under the skilled handling of Rhys Jenkins and Henry Dickinson;[8] the first large-scale invention and use of machine tools in the great London workshops in the early years of the nineteenth century were directly and vividly described by the late Joseph Wickham Roe in his *English and American Tool Builders*.[9] In America, the interchangeable parts system which became the basis of the mass production of machines is given a cultural as well as a technological background in *The World of Eli Whitney* by Jeannette Mirsky and Allan Nevins.[10] The beginnings of automation in production lines of machine sequences are told by Greville Bathe in his biography of Oliver Evans.[11] Unfortunately, Bathe's *Engineer's Miscellany* was privately printed in only a limited edition.[12] These two books—the work of a true scholar—belong on the top shelf of histories of technology.

It is interesting to note that the results of the first researches into the past of American technology were published in the so-called trade journals, showing that the much-maligned "practical men" were, in fact, deeply interested in the origins of the machines and tools they used. *Iron Age*, *Abrasive Industry* and *American Machinist* were pioneers in this effort.

The broad surveys became more complete, authentic, and mature. The most definitive of these is *A History of Technology*, edited by Charles Singer and others,[13] but there are comprehensive briefer works such as Eric Hodgins' *Behemoth, the Story of Power*,[14] James K. Finch's *Engineering and Western Civilization*,[15] Hans Straub's *History of Civil Engineering*,[16] and *Engineering in History*[17] by Kirby, Withington, Darling, and Kilgour, which takes us back beyond 2000 B. C.

Why, then, this sudden late interest in this vital phase of history? And why the long literary neglect of basic "hardware" during which much, despite the zeal of today's researchers, must have been lost? And why in all the body of general history do we find so little attention to the technological facts of life? It may be instructive to inquire into the reasons for this cultural hiatus.

II

The curious obsession of historians which for centuries held them back from the whole truth was first attacked by Thomas

Babington Macaulay in the introduction to his *History of England*. "I shall cheerfully bear," he wrote, "the reproach of having descended below the dignity of history, if I can succeed in placing before the English of the nineteenth century a true picture of the life of their ancestors." This "dignity" with which history was expected to be clothed constrained Macaulay's contemporaries to "treat of battles and sieges, of the rise and fall of administrations, of intrigues in the palace, and of debates in the parliament." Macaulay proposed to shock his colleagues by describing "even the revolutions which have taken place in dress, furniture, repasts and public amusements." Furthermore, he intended to "trace the progress of useful and ornamental arts," distasteful as this might be to those who could not reconcile literature and mechanics, or, as we might express it, technology and culture.

Unhappily, Macaulay did not scotch the taboo. Through the nineteenth and even into the twentieth century the shadow of the obsession dimmed the writings of competent and otherwise thorough historians. As technics multiplied about us, the written history which ignored them became, to the ordinary reader, less and less credible and, to the student, duller and duller. The events it described hung *in vacuo*, divorced from physical causes, from the immediate necessities and commonplaces of life. Economic and political theories seemed to float in the air out of contact with such causal factors as, for example, the total revolutions in power, communication and transport, chemical engineering, and construction methods. How, let us say, can we entertain such abstractions as "urban growth and dispersion" without a thorough understanding of the development through mass production of the cheap automobile—specifically the Model-T Ford, the covered wagon of the twentieth century, which introduced a whole new epoch of pioneer migration and settlement?

My own memory of student days recalls a fog surrounding the whole subject—the "discipline," it was called—of history. The mere word was anathema and, where I could, I evaded every college course of it, ancient or modern. The life about me was far more exciting. Every day some new invention or discovery seemed to render obsolete those of the day before; in this progress there was something tangible, that one could get one's teeth in. The foreground view of it blocked out the panorama of abstrac-

tions behind. The Carthaginian wars, the fall of the Roman Empire, the Norman invasion, the Magna Carta, the discovery of America, the Wars of the Roses, the Spanish Inquisition, the French Revolution, the Louisiana Purchase, the Missouri Compromise were words with dates attached, loosely strung together by such terms and phrases as " the rise and fall of civilizations," " the struggle for liberty," " Renaissance," " Reformation," " Enlightenment "–abstractions cooked up out of hindsight to give " dignity " to the record.

It was only when I discovered from the exploration of rare or forgotten writings and artifacts that the vast gulfs between these events were filled with galleys and sailing ships, roads, wagons, mines, canals, magnetic compasses, catapults, crossbows, cannons, water wheels, muskets, machine tools, and, eventually, engines and dynamos that I began to see a real continuity and integrity to history.

My discovery came when Maxwell E. Perkins, then chief book editor of Charles Scribner's Sons–and, I think, the greatest editor of my time–suggested that I do a book on American invention. The suggestion horrified me at first as it conjured up memories of the juveniles I had seen about the " romance " of invention until he added that he meant a social history of the United States in terms of inventions and technologies. This seemed to me so novel an idea that, after a good deal of thought, I decided to try it. I began by searching the libraries to find a precedent for such a book. The dearth of such histories, at least in the field of American record, led me to believe that my book, if I could write it, might be a pioneer.

At this point, however, I came upon two books which did what I hoped to do, but on a world scale. One was Abbot Payson Usher's *History of Mechanical Inventions*,[18] which introduced me to the philosophy of invention and showed not only the response of technology to the social needs of the periods he examined but also its limitation by variations in other cultural levels. This limitation is, of course, best illustrated by Leonardo's dreams of devices which were impossible of realization in his day because of the lag in collateral technics. To me a signal service of this book was its scrapping of the old adage about invention and necessity. Not only, it appeared, might invention be sporadic–an experience abun-

dantly confirmed in Ralph Linton's *Study of Man* [19]—but invention is also frequently the mother of necessity, as we see in the modern world when each new technology gives birth to a host of needs. Here the classic example, perhaps, is the telephone, by no means a necessity in its time, which caused a universal readjustment in transportation, marketing techniques, business negotiation, and even architecture.

The other book, no less scholarly but, for the layman, more readable, was Lewis Mumford's *Technics and Civilization.*[20] Whether or not one agrees with his epochal classification, there can be little question that the book is a pioneer—perhaps the first in completeness of pattern—in breaking the tradition about which Macaulay complained and which had held so firm a grip on historians. To me it not only gave the inspiration that stretched my project into three volumes,[21] but it reformed my entire attitude toward cultural history. That it had this effect on many other writers who have since integrated technology into the continuity of civilization's record is evident from the recurrence of Mumford's title in their bibliographies.

The narrowness of my knowledge when I first experimented with this new kind of history was evident in a talk I had with Mr. Edwin Pugsley of the Winchester Repeating Arms Company in New Haven. He mentioned Eli Whitney, to which by a sort of reflex I said, "Oh yes, the cotton gin," which was the only association the vast majority of Americans had with this great inventor. Mr. Pugsley explained it was true that that piece of "hardware" was so important a causal factor of the Civil War that historians could not dodge it; yet it was a far less complex invention in itself than his system for the machine production of standardized interchangeable machine parts, a universal practice in the modern world. From there I moved into the deep effect of quantity production on the conquest of the American continent and the later necessity of mass production in changing the social geography of that continent by the cheap car. Finally, I came to know the importance of mass-produced "hardware" in the development of the equality concept.

III

Within the last generation, the trend toward making the history of technology an inherent part of all history has gained much ground. Instead of slavishly following the snobbish design of "dignified" history, writers have studied the works of the late Professor Ogburn, of Messrs. Peter Drucker, Howard Mumford Jones, Hornell Hart and other humanists and social scientists as guides to the integration of political, economic, social, and technical record. Certainly in American history this sort of reading has brought results in such books as Dirk J. Struik's *Yankee Science in the Making*,[22] John Kouwenhoven's *Made in America*,[23] the new *History of the United States* by William Miller,[24] and that monumental volume, *America as a Civilization*, by Max Lerner.[25]

The field, however, is still relatively empty. It offers wide opportunity. The tools for this all-embracing historiography are rapidly multiplying. As new discoveries in science and their new applications surround us more closely, the potential public is growing. That public is eager to know how the devices evolved as well as how they work, what has been their relation to human activity and environment and, thus, which of them is likely to help or hurt our current lives. Finally, the educational necessity is predominant. One of the greatest dangers we face is the narrowing circle of the scientific and technologically knowledgeable. The space between the instructed and the ignorant is widening toward the point where a majority in our society may abandon all power to the know-how few. Too many schoolchildren are taking the pushbutton world they live in for granted as though it had sprung fully armed from some Jovian head. If we can teach them of the slow, heart-breaking processes by which we came to be as we are, it will give them healthy pause.

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Ideas, History, Technology

HOWARD MUMFORD JONES*

WHEN IN 1936 Arthur O. Lovejoy published *The Great Chain of Being: A Study in the History of an Idea*, he demonstrated in its fullness an approach to cultural history, which, if not altogether novel, marked an alteration in historical writing as radical as was Turner's frontier thesis in the writing of American history. Associated with this volume were, of course, other books and essays by Lovejoy, his collaborators and his followers, and out of this activity came the impulse to create the *Journal of the History of Ideas* and the recently founded international organization of intellectual historians. I say that the theory of a history of ideas is not precisely novel because hints and proleptic examples of intellectual history before Lovejoy abound, and because in human affairs most innovations are anticipated or paralleled—one thinks in this connection of J. B. Bury's classic study of the idea of progress. But all this has nothing to do with the unique achievement of Lovejoy in creating a new discipline in history by precept, theory, and example. The history of ideas (or intellectual history) is now a standard part of historical scholarship.

Professor Lovejoy's concern was with what he thought of as unit ideas. He was interested, as it were, in getting philosophy out of a tight departmental box, but he was also interested in calling the attention of scholars in other disciplines to the fact that they had been dealing with philosophy all their lives without knowing it. In truth, general ideas are not necessarily metaphysical ones. Powerful ideas are not always consistent with themselves; and, moreover, in proportion as they are influential, they may be suffused with emotion, with passion, with " drive," sometimes to such

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a degree that they virtually cease to be intelligible. What was really meant by "liberty" in much of the seventeenth, eighteenth, and nineteenth centuries of the Western world? "Liberty" was sometimes powerfully embodied in painting or sculpture by a vigorous female with a Phrygian cap on her head, her mouth open as if screaming, her bare or sandalled feet almost lifting her from the ground. Is this the same "liberty" as the quiet classical maiden in repose, standing, or sitting in a curule chair, or pictured on a coin, a look of vacant pride on her regular features? What, for that matter, is "liberty under law"? What is "liberty of conscience"? What is "at liberty"? What is "liberty to withdraw"? Are all these the same things as the second element of "life, liberty, and the pursuit of happiness"?

Professor Lovejoy once demonstrated in a brilliant essay that "romanticism" does not have meaning, but meanings; and he and his followers have performed similar feats with words like "nature." This may be called historical semanticism applied to a general term. The movement toward a stricter semantic analysis of unit ideas has of course been strengthened by the logical positivists, by the new canon of linguistic study, and by allied analytical movements, so much so, indeed, that a metaphysician nowadays scarcely dare lay down any general proposition. An unexpected consequence has been to impoverish philosophy as a guide to life in the very process of expanding and extending the range of philosophical inquiry. But this is to digress.

Lovejoy, as I say, took for granted something he thought of as a unit idea—some powerful concept that, refusing to be chained to a closed intellectual system, gets loose, as it were, and ranges widely in time and through human activity, taking on protean shapes as it does so. I think it is fair comment to observe that Mr. Lovejoy never quite defined or delimited the concept of a unit idea. A unit idea for purposes of historical investigation is not so much some simple or absolute concept perpetually modified as its contexts change as it is a summation of approaches to a concept, a kind of composite photograph of what various persons at various times have thought they meant when they wrote or uttered some word or phrase or sentence or passage aimed in the general direction of the idea and hitting some point in the target, but not necessarily the central point. For operational purposes the historian of ideas

does not need metaphysical acuity, since it is precisely a bloodless dance of the categories that he wants to avoid. The unit of thought, whatever else is meant by it, has a distinct life of its own, and its life, however variegated, is, so to speak, its definition.

An important limitation on the method, or upon the fields in which the method has customarily been applied, presently appeared. Whatever one means by the history of ideas (or intellectual history), the ideas with which one concerns oneself have been, in the main, literary concepts—and here I use " literary " in that general sense one has in mind when one speaks of the literature of a subject, and without reference to belles lettres except in so far as belles lettres has furnished evidence to the historian of ideas. Any unit idea has to be recorded in words, and these words commonly have taken shape as some sort of document. If, for example, one pursues a unit idea like " the innocence of childhood," one collects historical evidence for the origin, growth, and change in this idea from philosophers, theologians, poets, novelists, painters, psychologists, physicians, and the like, but the evidence almost invariably appears in " literary " form—a document, a poem, a play, a report, a theory of psychology, a legal decision, and so on. (The evidence in painting or sculpture or, for that matter, music, is of course of another sort.) What the illiterate or the inexpressive thought about childhood cannot be directly discovered and is only indirectly analyzable from the written report of somebody else. How, indeed, can the historian of ideas otherwise operate? His material has, for the most part, to take shape as words.

Inevitably, however, limitations appear. He who is trained to scholarly orthodoxy tends to look for what he wants in the right places only; and the right places have been in records and documents and works of art containing some degree of generalized or philosophical implication and evincing a greater or lesser quality of orthodox respectability. A peace treaty, a poem, a painting, a system of philosophy, an anthropological report possess academic respectability; a lever or an ink eraser does not. Historical evidence is, and has been, curiously " literary." Thus a hundred scholars know something about Lucretius for one who realizes what a revolution in human culture took place in the ninth century when Western man put draft harnesses on his horses instead of choking their windpipes with a rope attached to a cart. A hun-

dred scholars can discuss Darwin, a master of scientific prose, to one who knows that among the causes for the celerity of Napoleon's armies is the fact that Napoleon knew how to exploit the Chappe telegraph, whereas his opponents—the Austrians, for example—did not. The fortunes of the idea of progress can be traced in literary documents; the fortunes of the idea of interchangeable parts are somehow less attractive to the historian of ideas, or were until recently, at least. Among historians of ideas, then, a great deal of attention is given to the history of ideas expressed in literary form, and very little attention to the history of ideas, chiefly technological, not commonly so expressed. It would, however, be jejune to remark that the effect of the idea of interchangeable parts upon the fortunes of mankind has been quite as great as the effect of the idea of progress.

The situation should not, however, be naively glossed as evidence of the intellectual snobbery of humanists. The truth is that the records of technological advance are often lacking, or unintelligible, or difficult to interpret, or hard to come by. In the first place, scientist and inventor are not characteristically given to expressing themselves in words, or at least they are not given to expressing the elements of their discoveries in words, however loquacious they may be as private individuals. In the second place, inventions and discoveries are often unpleasing to the gods, the church, the state, the law, or custom; and the inventor, rather than risk loss of limb, life, or liberty, has sometimes kept his discovery to himself or delayed making a statement of his discovery or been protected by his pious friends. A classic instance is the long concealment of da Vinci's curious speculations about flying machines. In the third place, even when the inventor has had no cause to dread hostility, in periods before the wide extension of patent law, he has had to conceal his discovery from jealous rivals, communicating it only to a few trustworthy friends, sometimes in language so guarded or cryptic it is difficult to know what he said. Patent law, by the by, has not always resulted in the immediate revelation of discoveries to the public: witness litigation over telephone and automobile. And in the fourth place, machines and like inventions destroy themselves or are destroyed without replacement either by accident or design or enmity or neglect; or they are put aside and forgotten if they are not immediately acceptable to

society, with the result that the history of technology occasionally resembles the famous imperfections of the geological record that used to delight the opponents and trouble the defenders of biological evolution.

Even when the records are relatively complete, however, the ordinary historian is sometimes baffled. The records of inventions from older periods, say, the Middle Ages or the Renaissance, are necessarily written in the language of their time, so that it becomes necessary to translate an obsolete professional or technical vocabulary into modern terminology, a feat that requires a special blending of linguistic knowledge and knowledge of the history of science. Neither the general historian nor the special worker in intellectual history is inevitably possessed of both these skills. In modern times, moreover, the vocabulary of science develops, changes, drops certain technical terms, reinterprets old ones, and develops new words with such astonishing fluency that even historians of science do not attempt to cover the total modern field. Research in any patent office likewise requires some degree of special skill; and the historian of technology, once past these obstacles, has still to confront the vast problems of economic and sociological change created by, or creating, technological advance. It seems evident, therefore, despite everyone's distaste for creating more specialists, that investigation into the history of technology demands special training, special knowledge, and special skill. In the sense that machines or operations are unit ideas visibly expressed in matter, the historian of technology is a member of the company of intellectual historians; in the sense that his learning depends upon the history of science, he may be brigaded with that group of specialists—all of which is not to say that the history of science is separate from intellectual history.

Despite a scanty library of admirable books treating of the history of technology, not many of which, alas! are in English, research in the field is presently in a formative stage. Scholars are usefully at work collecting primary materials, and they have not yet reflected upon the philosophy of this branch of history. At the present time, for example, a straight-line narrative of increasing success in any form of invention suffices for an organizing pattern. As the evolution of the horse compels us, as it were, to arrange fossils and living animals in an ascending order from eohippus to

a living Kentucky stallion, so we arrange the " evolution " of technical invention along a similar simple line. Thus the success of the railway leads us to think of productions by persons like Cugnot and Trevithick as proto-locomotives eventuating in a modern Diesel locomotive. But machines are not living structures, and do not of themselves evolve. Furthermore, on such a line, whatever leads to the next step onward " succeeds " and whatever does not lead to the next step onward " fails."

But suppose the railway had not succeeded. Suppose that government and capital, instead of backing Stephenson, had backed some of the experimentation in steam velocipedes, those remote ancestors of the automobile, suppose that the palm had been given to the " horseless carriage " on the argument that it did not require a special highway—what, in that event, would have become of the evolution of inventions upward into the Diesel locomotive? If it be a platitude that history is a one-way process, is it therefore true that some inventors have historic luck and some do not? Is " progress " in technology a function of economic adaptation only? There are times when it seems to be so, and yet few of us are quite prepared, I think, to measure human ingenuity in terms of historical accident or economic determinism.

If success be translated into historical opportunism, is failure conditioned merely by arriving at the right spot but at the wrong time? The problem of historical relativism has, it seems to me, special poignancy in the field of technology; and we have not yet determined the criterion of importance down the long vista of time. In philosophy or literature a great production may lie hidden or undervalued for decades—the eighteenth century, for example, could make little out of Dante—and yet eventually take on primary importance for understanding man. The history of technology is also a way of understanding man, but I suggest that the " failures " may be more illuminating than the " successes." For in what did failure lie? Some ideas are patently absurd; for example, the notion of a platform lifted and drawn through the air by trained eagles, but other failures are not failures of brain power but of local and limited adaptation. A history of failure is badly needed, but it must be a just and generous history, not a superior attitude towards human folly. Above all, the historian of technology must avoid the vulgar error of believing that nothing succeeds like success.

There is also the problem of allocating priority and credit, tangled in such familiar cases as the history of photography, of the telegraph, and of the automobile. To the trained research worker in technological history it is self-evident that the case of an inventor who does everything by and in himself is such a *rara avis* as to be as legendary as the phoenix, but nationalistic prejudices enter the story, legend arises, and particular cultures insist that they have a monopoly on inventiveness. We laugh at this in the case of certain exuberant Russian claims, forgetting it is an article of faith in American schools that Fulton invented the steamboat, Morse the telegraph, Alexander Graham Bell the telephone, and Edison the motion picture. To the cultivated European savant this is a charming (or ugly) parochialism; and he will insist that, for example, you cannot come to Morse until you have considered such persons as Oersted, Faraday, Le Sage, Steinheil, and others. We do not know who invented the wheel, invented, to be sure, when there was no nationalism; but claims to priority with respect to this or that machine, method, innovation, or improvement, on behalf of one or another national culture do not always create international harmony. The odd thing is that these claims, pushed on behalf of some unknown national alleged to have anticipated some part or the whole of a particular technological innovation, frequently arise out of the very cultural pluralism, the essentially international character of technological advance. A claim is made, a dispute ensues, those who deny the claim are charged with acting from motives of national parochialism or jealousy, and the fat is in the fire. The famous dispute between the partisans of Leibnitz and of Newton with respect to " fluxions " is a type case; and if it seems to us nowadays a rather childish dispute, we forget a variety of later recriminations of like kind, aggravated sometimes by patent claims. But research into the history of technology will not advance humane culture if it stir up international jealousies, which, alas! it sometimes does. The intent of science is to avoid such disputes; and here, it seems to me, the historian of technology should ponder the example of the gentle and lamented George Sarton, historian of science *par excellence* and embodiment of the qualities of humane learning to a degree not always attained by professional humanists.

One final problem: the lay reader. The research worker in this

field is under no obligation whatsoever to strive for what the French call *vulgarisation*. He operates as an expert speaking to experts in the language of his specialty. If, however, the importance of the history of technology in general culture is to be recognized, if its contribution to humane learning is to be just, active, and full, then it cannot leave writing for the lay reader to popular journalism. The popular book on the history of technology, at least in my experience, tends to a false dramatization of the subject, it adopts a romantic conception of "genius," it falsifies the relation between technological advance and the economic order, it is frequently inaccurate in its facts, and it ends by uncritically assuming that current industrial culture is the best possible culture in this best of all possible worlds.

The popular book, nevertheless, has two enormous advantages: its illustrations are usually full, excellent, and, in large degree, properly documented; and its expository prose is commonly direct, clear, and cogent. The historian of technology is under some obligation to the general public—otherwise, the importance of his subject remains forever in the hands of journalists and their kind of popularizer—and he may well ponder the qualities that make popular manuals readable and appealing. He must also, it seems to me, open relations with the general historian if technology is to be properly treated in general histories (political, social, and economic histories especially). These general books are coming more and more to understand that war and diplomacy are not nine-tenths of life, and are giving more serious attention to the development of literature, the arts, recreation, and religion in any national culture. But, no doubt because of the difficulties of the subject, the discussion of technology in most of these books is, I think, naive. The opportunity for the historian of technology, either as collaborator, contributor, or consultant, to redress the balance in such volumes is an open one, and I trust that some scholars in the field will see it.

Work and Tools

PETER F. DRUCKER*

I

MAN, ALONE OF ALL animals, is capable of purposeful, nonorganic evolution; he makes tools. This observation by Alfred Russell Wallace, co-discoverer with Darwin of the theory of evolution, may seem obvious if not trite. But it is a profound insight. And though made some seventy or eighty years ago, its implications have yet to be thought through by biologists and technologists.

One such implication is that from a biologist's (or a historian's) point of view, the technologist's identification of tool with material artifact is quite arbitrary. Language too is a tool, and so are all abstract concepts. This does not mean that the technologist's definition should be discarded. All human disciplines rest after all on similarly arbitrary distinctions. But it does mean that technologists ought to be conscious of the artificiality of their definition and careful lest it become a barrier rather than a help to knowledge and understanding.

This is particularly relevant for the history of technology, I believe. According to the technologist's definition of "tool," the abacus and the geometer's compass are normally considered technology, but the multiplication table or a table of logarithms are not. Yet this arbitrary division makes all but impossible the understanding of so important a subject as the development of the technology of mathematics. Similarly the technologist's elimination of the fine arts from his field of vision blinds the historian of technology to an understanding of the relationship between scientific knowledge and technology. (See, for instance, volumes III and IV of Singer's

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monumental *A History of Technology*.) For scientific thought and knowledge were married to the fine arts, at least in the West, long before they even got on speaking terms with the mechanical crafts: in the mathematical number theories of the designers of the Gothic cathedral,[1] in the geometric optics of Renaissance painting, or in the acoustics of the great Baroque organs. And Lynn T. White, Jr. has shown in several recent articles that to understand the history and development of the mechanical devices of the Middle Ages we must understand something so non-mechanical and non-material as the new concept of the dignity and sanctity of labor which St. Benedict first introduced.

Even within the technologist's definition of technology as dealing with mechanical artifacts alone, Wallace's insight has major relevance. The subject matter of technology according to the Preface to *A History of Technology* is " how things are done or made "; and most students of technology to my knowledge agree with this. But the Wallace insight leads to a different definition: the subject matter of technology would be " how man does or makes." As to the meaning and end of technology, the same source, again presenting the general view, defines them as " mastery of his (man's) natural environment." Oh no, the Wallace insight would say (and in rather shocked tones): the purpose is to overcome man's own natural, i. e., animal, limitations. Technology enables man, a land-bound biped, without gills, fins or wings, to be at home in the water or in the air. It enables an animal with very poor body insulation, that is, a sub-tropical animal, to live in all climate zones. It enables one of the weakest and slowest of the primates to add to his own strength that of elephant or ox, and to his own speed that of the horse. It enables him to push his life span from his " natural " twenty years or so to threescore years and ten; it even enables him to forget that natural death is death from predators, disease, starvation, or accident, and to call death from natural causes that which has never been observed in wild animals: death from organic decay in old age.[2]

These developments of man have, of course, had impact on his natural environment—though I suspect that until recent days the impact has been very slight indeed. But this impact on nature outside of man is incidental. What really matters is that all these developments alter man's biological capacity—and not through the

random genetic mutation of biological evolution but through the purposeful non-organic development we call "technology."

What I have called here the "Wallace insight," that is, the approach from human biology, thus leads to the conclusion that technology is not about things: tools, processes, and products. It is about work: the specifically human activity by means of which man pushes back the limitations of the iron biological law which condemns all other animals to devote all their time and energy to keeping themselves alive for the next day, if not for the next hour. The same conclusion would be reached, by the way, from any approach, for instance, from that of the anthropologist's "culture," that does not mistake technology for a phenomenon of the physical universe. We might define technology as human action on physical objects or as a set of physical objects characterized by serving human purposes. Either way the realm and subject matter of the study of technology would be human work.

II

For the historian of technology this line of thought might be more than a quibble over definitions. For it leads to the conclusion that the study of the development and history of technology, even in its very narrowest definition as the study of one particular mechanical artifact (either tool or product) or a particular process, would be productive only within an understanding of work and in the context of the history and development of work.

Not only must the available tools and techniques strongly influence what work can and will be done, but how it will be done. Work, its structure, organization, and concepts must in turn powerfully affect tools and techniques and their development. The influence, one would deduce, should be so great as to make it difficult to understand the development of the tool or of the technique unless its relationship to work was known and understood. Whatever evidence we have strongly supports this deduction.

Systematic attempts to study and to improve work only began some seventy-five years ago with Frederick W. Taylor. Until then work had always been taken for granted by everyone—as it is still, apparently, taken for granted by most students of technology. "Scientific management," as Taylor's efforts were called misleadingly ("scientific work study" would have been a better

term and would have avoided a great deal of confusion), was not concerned with technology. Indeed, it took tools and techniques largely as given and tried to enable the individual worker to manipulate them more economically, more systematically, and more effectively. And yet this approach resulted almost immediately in major changes and development in tools, processes, and products. The assembly line with its conveyors was an important tool change. An even greater change was the change in process that underlay the switch from building to assembling a product. Today we are beginning to see yet another powerful consequence of Taylor's work on individual operations: the change from organizing production around the doing of things to things to organizing production around the flow of things and information, the change we call "automation."

A similar, direct impact on tools and techniques is likely to result from another and even more recent approach to the study and improvement of work: the approach called variously "human engineering," "industrial psychology," or "industrial physiology." Scientific management and its descendants study work as operation; human engineering and its allied disciplines are concerned with the relationship between technology and human anatomy, human perception, human nervous system, and human emotion. Fatigue studies were the earliest and most widely known examples; studies of sensory perception and reaction, for instance of airplane pilots, are among the presently most active areas of investigation, as are studies of learning. We have barely scratched the surface here; yet we know already that these studies are leading us to major changes in the theory and design of instruments of measurement and control, and into the re-design of traditional skills, traditional tools, and traditional processess.

But of course we worked on work, if only through trial and error, long before we systematized the job. The best example of scientific management is after all not to be found in our century: it is the alphabet. The assembly line as a concept of work was understood by those unknown geniuses who, at the very beginning of historical time, replaced the aristocratic artist of warfare (portrayed in his last moments of glory by Homer) by the army soldier with his uniform equipment, his few repetitive operations, and his regimented drill. The best example of human engineering

is still the long handle that changed the sickle into the scythe, thus belatedly adjusting reaping to the evolutionary change that had much earlier changed man from crouching quadruped into upright biped. Everyone of these developments in work had immediate and powerful impact on tools, process, and product, that is, on the artifacts of technology.

The aspect of work that has probably had the greatest impact on technology is the one we know the least about: the organization of work.

Work, as far back as we have any record of man, has always been both individual and social. The most thoroughly collectivist society history knows, that of Inca Peru, did not succeed in completely collectivizing work; technology, in particular, the making of tools, pottery, textiles, cult objects, remained the work of individuals. It was personally specialized rather than biologically or socially specialized, as is work in a beehive or in an ant heap. The most thoroughgoing individualist society, the perfect market model of classical economics, presupposed a tremendous amount of collective organization in respect to law, money and credit, transportation, and so on. But precisely because individual effort and collective effort must always be calibrated with one another, the organization of work is not determined. To a very considerable extent there are genuine alternatives here, genuine choices. The organization of work, in other words, is in itself one of the major means of that purposeful and non-organic evolution which is specifically human; it is in itself an important tool of man.

Only within the very last decades have we begun to look at the organization of work.[3] But we have already learned that the task, the tools, and the social organization of work are not totally independent but mutually influence and affect one another. We know, for instance that the almost pre-industrial technology of the New York women's dress industry is the result not of technological, economic, or market conditions but of the social organization of work which is traditional in that industry. The opposite has been proven, too: When we introduce certain tools into locomotive shops, for instance, the traditional organization of work, the organization of the crafts, becomes untenable; and the very skills that made men productive under the old technology now become a major obstacle to their being able to produce at all. A good case

can be made out for the hypothesis that modern farm implements have made the Russian collective farm socially obsolete as an organization of work, have made it yesterday's socialist solution of farm organization rather than today's, let alone tomorrow's.

This interrelationship between organization of work, tasks, and tools must always have existed. One might even speculate that the explanation for the mysterious time-gap between the early introduction of the potter's wheel and the so very late introduction of the spinning wheel lies in the social organization of spinning work as a group task performed, as the Homeric epics describe it, by the mistress working with her daughters and maids. The spinning wheel with its demand for individual concentration on the machinery and its speed is hardly conducive to free social intercourse; even on a narrowly economic basis, the governmental, disciplinary, and educational yields of the spinning bee may well have appeared more valuable than faster and cleaner yarn.

If we know far too little about work and its organization scientifically, we know nothing about it historically. It is not lack of records that explains this, at least not for historic times. Great writers—Hesiod, Aristophanes, Virgil, for instance—have left detailed descriptions. For the early empires and then again for the last seven centuries, beginning with the high Middle Ages, we have an abundance of pictorial material: pottery and relief paintings, woodcuts, etchings, prints. What is lacking is attention and objective study.

III

The political historian or the art historian, still dominated by the prejudices of Hellenism, usually dismisses work as beneath his notice; the historian of technology is "thing-focused." As a result we not only still repeat as fact traditions regarding the organization of work in the past which both our available sources and our knowledge of the organization of work would stamp as old wives' tales, but we also deny ourselves a fuller understanding of the already existing and already collected information regarding the history and use of tools.

One example of this is the lack of attention given to materials-moving and materials-handling equipment. We know that moving things—rather than fabricating things—is the central effort in pro-

duction. But we have paid little attention to the development of materials-moving and materials-handling equipment.

The Gothic cathedral is another example. H. G. Thomson in *A History of Technology* (II, 384) states for instance flatly "there was no exact medieval equivalent of the specialized architect" in the Middle Ages; there was only "a master mason." But we have overwhelming evidence to the contrary (summarized, for instance, in Simson [4]); the specialized, scientifically trained architect actually dominated. He was sharply distinguished from the master mason by training and social position. Far from being anonymous, as we still commonly assert, he was a famous man, sometimes with an international practice ranging from Scotland to Poland to Sicily. Indeed, he took great pains to make sure that he would be known and remembered, not only in written records but above all by having himself portrayed in the churches he designed in his full regalia as a scientific geometer and designer–something even the best-known of today's architects would hesitate to do. Similarly we still repeat early German Romanticism in the belief that the Gothic cathedral was the work of individual craftsmen. But the structural fabric of the cathedral was based on strict uniformity of parts. The men worked to moulds which were collectively held and administered as the property of the guild. Only roofing, ornaments, doors, statuary, windows, and so on, were individual artists' work. Considering both the extreme scarcity of skilled people and the heavy dependence on local, unskilled labor from the countryside, to which all our sources attest, there must also have been a sharp division between the skilled men who made parts and the unskilled who assembled them under the direction of a foreman or a gang boss. There must thus have been a fairly advanced materials-handling technology which is indeed depicted in our sources but neglected by the historians of technology with their uncritical Romanticist bias. And while the moulds to which the craftsman worked are generally mentioned, no-one, to my knowledge, has yet investigated so remarkable a tool, and one that so completely contradicts all we otherwise believe we know about medieval work and technology.

I do not mean to suggest that we drop the historical study of tools, processes, and products. We quite obviously need to know much more. I am saying first that the history of work is in itself

a big, rewarding and challenging area which students of technology should be particularly well equipped to tackle. I am saying also that we need work on work if the history of technology is truly to be history and not just the engineer's antiquarianism.

IV

One final question must be asked: Without study and understanding of work, how can we hope to arrive at an understanding of technology?

Singer's great *History of Technology* abandons the attempt to give a comprehensive treatment of its subject with 1850; at that time, the editors tell us, technology became so complex as to defy description, let alone understanding. But it is precisely then that technology began to be a central force and to have major impact both on man's culture and on man's natural environment. To say that we cannot encompass modern technology is very much like saying that medicine stops when the embryo issues from the womb. We need a theory that enables us to organize the variety and complexity of modern tools around some basic, unifying concept.

To a layman who is neither professional historian nor professional technologist, it would moreover appear that even the old technology, the technology before the great explosion of the last hundred years, makes no real sense and cannot be understood, can hardly even be described, without such basic concepts. Every writer on technology acknowledges the extraordinary number, variety, and complexity of factors that play a part in technology and are in turn influenced by it: economy and legal system, political institutions and social values, philosophical abstractions, religious beliefs, and scientific knowledge. No one can know all these, let alone handle them all in their constantly shifting relationship. Yet all of them are part of technology in one way or another, at one time or another.

The typical reaction to such a situation has of course always been to proclaim one of these factors as *the* determinant—the economy, for instance, or the religious beliefs. We know that this can only lead to complete failure to understand. These factors profoundly influence but do not determine each other; at most they may set limits to each other or create a range of opportunities

for each other. Nor can we understand technology in terms of the anthropologist's concept of culture as a stable, complete and finite balance of these factors. Such a culture may exist among small, primitive, decaying tribes, living in isolation. But this is precisely the reason why they are small, primitive, and decaying. Any viable culture is characterized by capacity for internal self-generated change in the energy-level and direction of any one of these factors and in their interrelationships.

Technology, in other words, must be considered as a system,[5] that is, a collection of interrelated and intercommunicating units and activities.

We know that we can study and understand such a system only if we have a unifying focus where the interaction of *all* the forces and factors within the system registers some discernible effect, and where in turn the complexities of the system can be resolved in one theoretical model. Tools, processes, products, are clearly incapable of providing such focus for the understanding of the complex system we call " technology." It is just possible, however, that work might provide the focus, might provide the integration of all these interdependent, yet autonomous variables, might provide one unifying concept which will enable us to understand technology both in itself and in its role, its impact on and relationships with values and institutions, knowledge and beliefs, individual and society.

Such understanding would be of vital importance today. The great, perhaps the central, event of our times is the disappearance of all non-Western societies and cultures under the inundation of Western technology. Yet we have no way of analyzing this process, of predicting what it will do to man, his institutions and values, let alone of controlling it, that is, of specifying with any degree of assurance what needs to be done to make this momentous change productive or at least bearable. We desperately need a real understanding, and a real theory, a real model of technology.

History has never been satisfied to be a mere inventory of what is dead and gone—that indeed is antiquarianism. True history always aims at helping us understand ourselves, at helping us make what shall be. Just as we look to the historian of government for a better understanding of government, and to the historian of art for a better understanding of art, so we are entitled to look to the

historian of technology for a better understanding of technology. But how can he give us such an understanding unless he himself has some concept of technology and not merely a collection of individual tools and artifacts? And can he develop such a concept unless work rather than things becomes the focus of his study of technology and of its history?

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[1] S. B. Hamilton only expresses the prevailing view of technologists when he says (in Singer's *A History of Technology*, IV, 469) in respect to the architects of the Gothic cathedral and their patrons that there is "nothing to suggest that either party was driven or pursued by any theory as to what would be beautiful." Yet we have overwhelming and easily accessible evidence to the contrary; both architect and patron were not just "driven," they were actually obsessed by rigorously mathematical theories of structure and beauty. See, for instance, Sedlmayer, *Die Entstehung der Kathedrale* (Zurich, 1950); Von Simson, *The Gothic Cathedral* (New York, 1956); and especially the direct testimony of one of the greatest of the cathedral designers, Abbot Suger of St. Denis, in *Abbot Suger and the Abbey Church of St. Denis*, ed. Erwin Panofsky (Princeton, 1946).

[2] See on this P. B. Medawar, the British biologist, in "Old Age and Natural Death" in his *The Uniqueness of the Individual* (New York, 1957).

[3] Among the studies ought to be mentioned the work of the late Elton Mayo, first in Australia and then at Harvard, especially his two slim books: *The Human Problems of an Industrial Civilization* (Boston, 1933) and *The Social Problems of an Industrial Civilization* (Boston, 1945); the studies of the French sociologist Georges Friedmann, especially his *Industrial Society* (Glencoe, Illinois, 1955); the work carried on at Yale by Charles Walker and his group, especially the book by him and Robert H. Guest: *The Man on the Assembly Line* (Cambridge, Massachusetts, 1952). I understand that studies of the organization of work are also being carried out at the Polish Academy of Science but I have not been able to obtain any of the results.

[4] Von Simson, *op. cit.*, pp. 30 ff.

[5] The word is here used as in Kenneth Boulding's "General Systems Theory—The Skeleton of Science," *Management Science*, II, no. 3 (April 1956), 197, and in the publications of the Society for General Systems Research.

The Scientist and the "Improver" of Technology

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SCIENCE, ACCORDING TO one of its leading historians, is "systematized positive knowledge." [1] Technology, according to another authority, is concerned with "systematic discourse about the (useful) arts." [2] Other definitions could be compiled indefinitely, not merely because of differences of viewpoint, but because the signification of the terms has evolved along with their subject matter. The evolution of technology, for example, has involved the differentiation of the "useful" from the "fine" arts, as suggested by the above definition. This differentiation is never perfect and becomes progressively less so as we peer into the more distant past.[3]

These terminological difficulties can be greatly diminished if one goes behind the abstract to the human reality and considers the scientists and the technologists themselves. Despite the fact that most, if not all, figures in the history of science and technology are to some degree involved in both, eminence in both is extremely rare.[4] One or the other field is usually clearly dominant in any given individual, and there is a surprising degree of agreement as to who were the important scientists and who the technologists.

There are other difficulties, however. In modern times science carries the connotation of the advancement of knowledge, not a mere static description of it; the scientist is one who acts to increase it. Technology, on the other hand, has been commonly understood merely to describe the useful arts as they are at any given time. The improver of technology has not always had a generally accepted name, nor has its improvement been thought of as a continuing activity until recent times. Historically, the improver has most frequently been called an "inventor," but as invention has been more narrowly defined by patent law, this name

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has become inadequate. "Engineer" is now the fashionable name for the improver of technology, although scarcely more adequate, as it originally, and essentially still, refers to the expert practitioner of one of the arts, who may or may not also be its improver. Because of these difficulties we will here refer to this individual as an "improver" of technology, an accurate though awkward description.

After many centuries during which they played obscure, if not minor, roles in the drama of human history, the scientist and the improver of technology have captured leading parts, or have, at least, been thrust into the center of the stage. Philosophers and critics of human affairs have belatedly begun the task of explaining them and their activities. Not the least difficulty in this undertaking is the peculiar interrelationship of science and technology, which varies markedly with the time, place, and attitude of the viewer. Until recently it has been given little serious attention from any viewpoint, and the history of the relationship, which must be consciously or unconsciously the basis of any discussion, has scarcely been studied at all. This question of the relationship between science and technology becomes most meaningful when translated into a historical comparison of the activities and attitudes of the scientist and his counterpart in technology, its improver.

The archaeological evidences of the earliest civilizations are largely technological in character. Science, being more dependent upon the written word, has left no evidence of comparable antiquity, although, if appropriately defined, it can be held to have preceded technology. Our earliest materials adequate to a study of the relationship between the two come from ancient Greece.

Pre-Socratic Greek philosophy (sixth century B. C.) is credited with the introduction of cosmology, based upon the conception of an orderly universe susceptible to human understanding, and Greek philosophy of the classical period invented a general and abstract mathematics. In Alexandria these elements were blended in a physical science which proved as productive as any up to our own time. Technology made no such spectacular advance under the Greeks (although we know that it was not static), nor is it clear that it exercised much influence on the Greek scientist, who was characteristically contemptuous of manual labor.

During the Greek period attention was occasionally given by

scientists to civil and military engineering, technologies which are particularly esteemed by governments and which have always had a peculiar relationship to science.[5] The Romans gave these special technologies relatively more attention and science relatively less. By comparison, the attention given by scientists to the improvement of such basic technologies as the production of foods, minerals, and material amenities (consumer goods) was insignificant.[6]

The decline of Greek science has been and remains a lively subject of inquiry in the history of science. Most prominent among the causal factors adduced are the exhaustion of the possibilities inherent in its basic methodology, the rise of adverse political and philosophical factors, and the Greeks' failure to utilize the evidences of technology.[7]

The Middle Ages in Europe established a completely new system of relationships between philosophy, science, and technology. Moral philosophy, based on theology, was the particular interest of this time, and the whole of philosophy was reoriented in this direction. Respect for manual labor was established, but experimental science gained no profit therefrom, for science was not regarded as a morally useful pursuit. The result was for science a further contraction of activity,[8] and for technology a trend towards the improvement of the useful arts, but one so gradual that it has gone unnoticed until recently even by historians.

From the mid-sixteenth century, we again encounter literary evidence of activity in science, notably in a series of treatises on astronomy and mechanics which resumed active consideration of these sciences approximately where antiquity had left off. Because of the intricate interrelationship of all of the elements of medieval philosophy, this revision of a relatively minor element finally threatened the whole edifice and, in fact, shook it to its foundations in what has become known as "the scientific revolution."[9]

Astronomy and mechanics formed the vanguard of the scientific revolution. Among the principal factors in its origin were a revival of interest in ancient (and some medieval) literature, including that of science, and the invention of the experimental method of investigation.[10] The former was an aspect of the intellectual revival of the later Middle Ages and the Renaissance cult of ancient Greece. It disinterred, among other things, the main body of the

works of Archimedes, the principal exponent in antiquity of the mathematical and quantitative view of physical problems, and the most eminent ancient scientist to concern himself with technological problems. But the experimental method of the seventeenth century was little more than hinted at in this literature. Its rise was also favored by the existence of a sympathetic interest on the part of the scientist in the useful arts. This interest led to his direct participation in the traditionally scientific technologies, civil and military engineering, and to a significant establishment of communication with the craftsmen of the instrument trade. If the rise of the idea of an ordered universe and the application of mathematics to the description of nature may be cited as preconditions of Alexandrian science, the recovery of ancient science and the application to science of techniques derived from the arts and crafts may be cited as those of modern science.

Like his ancient predecessor Archimedes, the seventeenth century scientist brought his talent directly to bear on civil and military engineering, with occasional excursions into applied mechanics and optics. But Archimedes did not typify the science of antiquity and did not, in fact, take his own technological work very seriously, whereas the technologically oriented scientist was commonplace in the seventeenth century. The majority of those remembered for their scientific work in mechanics, for example, were either engaged in the improvement of technology, as in military ordnance (Tartaglia, Galileo) and hydraulic engineering (Stevin), the improvement of power machinery (Leibniz, Huygens), or in the utilization of technology for the purposes of experimental science, as in the improvement of the telescope, which engaged Galileo, Torricelli, Descartes, Huygens, and Newton. In this generality of interest in technology the science of the seventeenth century differed radically from that of antiquity.

The utilization of technology for the purposes of experimental science brought the scientist into what proved to be a most fruitful communication with the instrument-maker. The latter had flourished during the sixteenth century in a field which should probably be classified as a fine art, the making of the decorative astrolabes, sundials, and compasses which were then in fashion. The clock-and-watch-maker was only slightly less closely associated with the fine arts. The scientist actually involved himself in instrument-

making on occasion, but, more often, he depended upon the instrument-maker to implement his own ideas. This close relationship between the scientist and instrument-maker has continued to the present day.

As regards the technologies of basic production, the sympathetic interest of the scientist was simply that, and it is difficult to detect many significant improvements attributable to science.[11] Perhaps this reflects the fact that these technologies had increased greatly in complexity, along paths strange to science. Thanks to the unsung medieval technologist, agriculture, navigation, mining, and other industries had been greatly improved.[12] In this area, the greatest service of science to technology in the seventeenth century was the sympathetic support extended to the craftsman and inventor. Not only were the practitioners of the arts frequently extolled, but some, such as the instrument-maker, were more or less taken into the scientific community. Towards the end of the century, we first encounter men clearly identifiable as improvers of technology, such as Morland, de Caus, and Polhem, and we encounter them principally because of their association with princely enterprises and the scientific societies.

The technologies of basic production had already reached such a level in the seventeenth century as to be largely beyond the power of the still nascent sciences to improve them. In the eighteenth century physicists are more often found endeavoring to explain the workings of some existing machine than suggesting improvements in it.[13] For the improvement of technology by the technologists themselves accelerated in that century to the degree that historians have found in it another revolution, the Industrial Revolution. This vast expansion of technology had as its central theme a succession of interrelated improvements in power machinery, iron metallurgy, and textile machinery. The fundamental inventions in power machinery were made during three decades before 1715, and involved scientists as well as technologists. The subsequent improvement of the steam engine, however, came increasingly into the hands of the technologist, and the improvement of iron metallurgy in the first half of the century and of textile machinery in the latter half seem to have owed very little to science.[14]

The livelihood of the scientist in the seventeenth century was

typically accomplished through his attachment to a court, although a few, notably in Italy, were associated with universities. In the next century men of independent means became prominent among active scientists, as did professional men, such as physicians and clergymen, who pursued science as an avocation. Not until the nineteenth century was well under way do we find the university a significant source of support and the typical scientist a professor. The improver of technology had no employment problem, for his natural habitat was in the ranks of employed workmen. His problem was to differentiate himself from the mass of his fellow workers who merely produced and to achieve recognition as one who improved the methods of production—as an inventor. The guild system and the lack of a patent system made the medieval inventor a troublesome member of society who was likely to be locked up. In his "proper place," he was a useful, but not clearly distinguishable, member of society, whereas the scientist was distinguishable enough, but not generally regarded as useful. In struggling against their respective disabilities, both were seeking a status in society.

A stable economic basis for the support of both the scientist and the improver of technology was established in the nineteenth century. The former was finally able to look beyond government employment and private patronage to the university. The latter achieved a measure of status through the patent law, which certified him to be an inventor, and hence distinguished him from the craftsman and production worker.[15] The increasing sophistication of the inventor and the emphasis placed on application by the scientist often made it unclear who was the scientist and who the inventor.[16] This trend towards amalgamation was reversed in the latter half of the century, however, as the advance of science accelerated to such a degree that its discoveries were no longer easily translated into utilitarian terms, while the technologist—now an engineer—became increasingly confident of the unlimited possibilities of pure empiricism.[17] The acceptance of the scientist by the universities also tended to return him to the camp of the philosopher, while the growth and prosperity of industry tended to identify the inventor with business, thus creating a relationship reminiscent of that of the antagonistic philosophers and tradesmen of antiquity.

The twentieth century has seen a marked trend towards the

reconciliation of the scientist and the improver of technology, the principal cause of which is the increasing dependence of technology on science. Synthetic organic chemistry, developed in the third quarter of the nineteenth century, was perhaps the first example of a production technology depending extensively and continuously on the scientist.[18] The electrical industry, despite its origins in science, remained within the competence of empirical technology until the rise of electronics in the twentieth century. Then it, too, has tended to become science-dominated.[19] Recent developments in metallurgy have brought the scientist into an important relationship to the iron industry, the traditional stronghold of the empirical technologist. Science has thus proved itself a factor to be reckoned with no less than economics in the conduct of a business.[20] The growth of these science-dominated technologies has been accompanied by a continuous extension of engineering education and a diminution of the proportion of engineers who are in a position to contrast experience with education realistically. There is a spectrum of specialities today which ranges from the pure scientist, on the one hand, through various degrees of applied science and engineering physics to, presumably, the pure improver of technology. The contrast between the frequency with which one hears of the first and the conspicuous diminution of the claims now made for pure empiricism is indicative of the degree to which science has permeated technology. But our concern for pure science is also indicative of the degree to which utilitarian considerations have been brought into science.

It is the unprecedented closeness of the partnership of science and technology today which gives rise to our concern with their relationship. It is reasonable to ask if any essential difference between the two really exists. The traditional distinction between knowledge and utility becomes somewhat shaky when subjected to close scrutiny. The association of science with discoveries and technology with inventions is even less reliable.[21] Yet one who studies the history of the subject is left with a feeling that, in scientists and improvers of technology, he is dealing with two different species, interdependent and even occasionally transmutable, but persistently distinct, like land- and water-dwelling creatures.

The importance of their interrelationship lies in the fact that, at a time when the idea of the dependence of technology upon science

is generally conceded, science has paradoxically continued to be regarded as an appendage of technology. In order to assure itself of public support which is indispensable, science is forced to engage in a continuous program of self-justification. If the history of its relationship with technology were better known this perpetual labor of Hercules might be made easier. I have made an attempt here to suggest certain aspects of this relationship at various times in the past for which we have at least general literature on the history of science and technology. But many questions important to this subject remain to be studied seriously. To what extent was Renaissance science dependent upon technology? To what extent was the technology developed in the Industrial Revolution indebted to science? To what degree was American technology in the nineteenth century indebted to European science? It seems beyond doubt that science and technology have had a generally beneficial interrelationship, and the development of one seems at times to have been decisively affected by events pertaining to the other. But in the present state of knowledge, conclusions are more easily drawn than substantiated.

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[2] Charles Singer, E. J. Holmyard, A. R. Hall, and T. I. Williams, eds., *A History of Technology* (5 vols., New York and London, 1954-1958), I, vii.

[3] On the differentiation of the useful from the fine arts, see A. R. Hall, "The Rise of the West," in Singer, *op. cit.*, III, especially p. 710.

[4] Stafford Hatfield finds only one example of this, Lord Kelvin.–*The Inventor and His World* (Pelican Books, 1948), p. 37.

[5] The differentiation of civil and military engineering from the production technologies is a constant factor through the history of science and technology until the late nineteenth century. In aiming at utility, civil and military engineering possess the essential characteristic of technology. They were considered among the arts in antiquity, and in modern times served as the nucleus around which was built the engineering profession as we now understand it. Yet their methods tend to be scientific, men who were principally scientists have at most times participated directly in their advancement, and civil and military engineering have until modern times been one of the most important sources of support for the impecunious scientist.

[6] R. J. Forbes, *Man the Maker* (New York, 1958), p. 62-64. Friedrich Klemm, *A History of Western Technology* (New York, 1959), pp. 18, 19, 28. Gordon Childe, *What Happened in History* (Pelican Books, 1942), p. 224.

[7] L. W. H. Hull, *History and Philosophy of Science* (London, 1959), Chap. 4,

emphasizes the first. Marshall Clagett, *Greek Science in Antiquity* (New York, 1955), Chap. 9, emphasizes the second. Benjamin Farrington, *Greek Science* (Pelican Books, 1949), II, Chap. 4, emphasizes the third.

[8] Medieval literature on science was not devoid of merit. A. C. Crombie points out that whereas seventeenth century writers were interested in specific scientific problems, medieval writers were primarily interested in the philosophy of science itself.–*Medieval and Early Modern Science* (rev. 2nd ed., New York, 1959), II, 115-116. On medieval work in mechanics, see René Dugas, *Histoire de la Méchanique* (Neuchâtel, 1950), Chaps. 3-5.

[9] See A. R. Hall, *The Scientific Revolution* (London, 1954) and Thomas Kuhn, *The Copernican Revolution* (Cambridge, Mass., 1957).

[10] Hall, *The Scientific Revolution*, p. 10 and Chap. VIII.

[11] R. K. Merton gives an extended account of the relationship between science and technology in England in his "Science, Technology and Society in Seventeenth Century England," *Osiris*, IV (1938), 360-632. His apparent conviction that British scientists played a significant role in technology is based on little more evidence than the now familiar case of the early steam engine. He acknowledges that technological change altogether during this century was "relatively slight," pp. 505, 506-513. In his *Ballistics in the Seventeenth Century* (Cambridge, 1952), A. R. Hall shows that the effect of the application of science to technology was slight, even where it was most direct.

[12] Forbes, *op. cit.*, p. 110. Klemm, *op. cit.*, pp. 79-86. Lynn White, "Technology and Invention in the Middle Ages," *Speculum*, XV (1940), pp. 141-159.

[13] See, for example, such a standard work as J. T. Desaguliers, *A Course of Experimental Philosophy* (2 vols., London, 1725-27).

[14] It is sometimes claimed that science had a powerful influence on technology in the eighteenth century. A. R. J. P. Ubbelohde, in Singer, *op. cit.*, III, pp. 671 ff., speaks of "the permeation of technology by science." Forbes, *op. cit.*, p. 183, claims that the great technological events of the eighteenth century could not have been possible without the background of scientific thought. But their evidence for this is in neither case very impressive. Klemm also leans to this view but admits that "England's course lay rather in the direction of purely practical experimentation." Names which can be associated with science are conspicuously absent from accounts of the iron and textile industries in the eighteenth century, and it does not appear that Lewis Mumford's view of the relative independence of technology has yet been disproved.–*Technics and Civilization* (New York, 1934), p. 215.

[15] Hatfield attributes the rise of the concept of invention to judiciary interpretation of the clause in the British Statute of Monopolies of 1624 decreeing that monopoly only be granted to the "true and first inventor." The judicature distinguished inventions from new manufactures which did not involve any addition to man's stock of useful expedients and devices.–*The Inventor and His World*, pp. 11-12. The problem of the inventor before this time is well illustrated by the case of the Nuremberg machinist, Hans Spaichl, recounted in Klemm, *op. cit.*, pp. 153 ff.

[16] Early American journals of science laid great stress on application. Silliman's *American Journal of Science* was "intended to enhance the circle of the physical sciences, with their application to the arts, and to every useful purpose." –I (1819), v. The introduction of the first volume of the journal, *Science* (1883), stated that "the leading feature of American science is its utilitarianism," adding, "nor is this to be at all regretted." On the other hand, Jacob Bigelow, whose

Elements of Technology (2nd ed., Boston, 1832) is sometimes credited with establishing the modern meaning of technology, described the work as the outgrowth of lectures "on the applications of the sciences to the useful arts." Andrew Ure, the apostle of nineteenth century industrialization, credited it to an ill-defined "physico-mechanical science,"–*Philosophy of Manufactures* (1835), cited by Klemm, *op. cit.*, p. 292. The president of the American Society of Mechanical Engineers, in his annual address for 1898, appears to have regarded the mechanical engineer as a scientist, and the ASME as a "scientific society."–*Transactions*, ASME, XX (1899), pp. 27 ff.

[17] In 1885, we find American Society of Mechanical Engineers' President J. F. Holloway stressing experience as the "source, from which, above all, [the mechanical engineer] will derive by far the most benefit."–*Transactions, ASME*, VII (1885-86), pp. 25 ff. He goes on to acknowledge the "great advantage" of "scientific and technical training," a qualification which his successor did not find it necessary to make.–*Transactions, ASME*, IX (1887-88), pp. 23 ff. These two engineers were self-trained. Their college-trained predecessor, R. H. Thurston, had been somewhat kinder to science. He exhorted the mechanical engineers to "find for these self-sacrificing students of science, pure and applied, means sufficient to enable them to work efficiently and productively."–*Transactions, ASME* I, (1880), pp. 1 ff.

[18] See L. F. Haber's interesting account of the "chemist-businessmen" who made the German dyestuffs industry and the contrast with the British United Alkali Company, which, in 1890, employed 50 chemists in 45 chemical works.–*The Chemical Industry in the Nineteenth Century* (Oxford, 1958), pp. 182-3, 186 ff.

[19] W. R. Maclaurin, *Invention and Innovation in the Radio Industry* (New York, 1949), pp. 250-51.

[20] Thirty years ago the ability of large corporations to manufacture cheaply was the question. Now it is their ability to produce innovations.–J. Jewkes, D. Sawers, and R. Stillerman, *The Sources of Invention* (London, 1958), p. 4.

[21] Contradictory use of these terms is commonplace, even among those who consciously try to differentiate them, such as Hull and Forbes, in the works cited here.

Technology and Social Change: Current Status and Outlook

FRANCIS R. ALLEN*

IN SETTING FORTH the state of development of the study of the influence of technology in producing social changes, we shall divide the subject into three main topics: (1) what has been accomplished in this field thus far; (2) what, looking toward the future, needs to be accomplished, including specific suggestions for research; and (3) brief comment concerning methodology for research on this subject.

Inasmuch as the study of social change itself constitutes a subfield of sociology, the study of technological influence upon social change is usually assumed to lie within the discipline of sociology. Indeed, courses bearing the title "Technology and Social Change" are invariably placed within the sociology curriculum. But many economists, anthropologists, historians, and other social scientists are also interested in this subject, and the precise label of a social scientist is not a matter of primary consequence when attention is focused upon a subject of common interest. Nor should our viewpoint be so narrow as to exclude physical scientists and engineers; they often are interested in the social effects of their creations. We hold to the principle that the gulf that seemingly separates technologists and social scientists would best be reduced or eliminated. Hence this article is addressed not only to sociologists but to all who are concerned with the social effects of technological productions.

ACCOMPLISHMENTS THUS FAR

The literature on technology and social change reveals that much has been accomplished as of the present time. Many sociologists, anthropologists, economists, and historians have made worthwhile

* Associate Professor of Sociology at Florida State University, Dr. Allen is editor and co-author of *Technology and Social Change* (1957).

contributions, as have journalists, social philosophers, and "general writers." Amid this abundant literature we must be careful to distinguish, however, between the social effects of technological inventions and developments (the defined subject of this article) and studies of the development of technology or of the use or non-use of inventions. The latter subjects are often fascinating and are essential, but they are not the main subjects under consideration here. Thus we are concerned here with the social effects of aviation or of television, not with the story of development of the airplane or the television set as an instrument, nor with the number of people who fly (or do not fly) or who watch television (or do not choose to do so) and what programs.

The number of users or adopters—or sometimes significantly the non-users—comprises one part of the subject under consideration, since social effects are not likely to be important if only a few people adopt an innovation.[1] In some instances studies of why people adopt or resist innovations are particularly valuable, and we shall point to some needed research on this phase of the subject later. With our central interest, then, relating to the various social effects of inventions—a considerable subject as major inventions usually have many direct and derivative effects—we turn to different categories of achievements which have already been made. These are: (1) general works or studies, (2) full scale studies of some one subject as television or automation, (3) smaller research projects, usually described in journal articles, and (4) textbooks, which are assumed to be summaries of the existing stock of knowledge. Since complete bibliographical listings are impossible in a short article, we can cite only examples of the contributions in the different categories.

General Works. Professor William F. Ogburn's volume *Social Change*, first published in 1922 and now widely regarded as a classic, was a general volume which highlighted the social influence of technology and invention. Proclaiming the importance of the cultural factor in social change (at the time undervalued at the expense of biological factors), it clarified the process of invention, described factors which tend to hinder cultural growth (as tradition, habit, and vested interests), pointed out the interrelations between different parts of culture (in the process stating the now-famous hypothesis of cultural lag), and cited the need for

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reasonable adjustment between human nature and culture (giving examples of several kinds of maladjustment).

In 1934 Lewis Mumford, social philosopher and prolific writer on a variety of subjects, wrote *Technics and Civilization*, which described the influence of the machine upon civilization from early times. Building on the earlier work of Patrick Geddes, Mumford posited three phases of the machine age—the eotechnic, paleotechnic, and neotechnic. With penetrating insight and colorful phrase he declared his views regarding the rightful, as well as the improper, place of the machine in the life of man. He also wrote *In the Name of Sanity* in 1954, which dealt with the impact of atomic technics, giving special attention to the nuclear bomb threat.

Anthropological volumes of interest include Professor Homer G. Barnett's *Innovation: The Basis of Cultural Change* (1953). Barnett discusses the setting for innovations, different kinds of incentives (including the desire for change), innovative processes, and factors related to the acceptance or rejection of innovations. Other anthropologists have made significant contributions to the technology-and-social-change subject as a part of their total work, notably A. L. Kroeber, Ralph Linton, and others on invention and diffusion, and Leslie White on the importance of sources of energy in the society. Professor W. Fred Cottrell, political and social scientist, has pointed to the significance of the use of energy (*Energy and Society*, 1955), relating his discussion largely to the full economic development, or underdevelopment, of the society.

Another general contribution of importance has been made by S. C. Gilfillan who, in an earlier (1935) work entitled *The Sociology of Invention*, discussed the nature and principles of invention and factors involved in the process, paying special attention to the inventors of ships.

Historical works of importance include Abbott Payson Usher's *A History of Mechanical Inventions* (revised, 1954), John W. Oliver's *History of American Technology* (1956), and the five-volume series edited by Charles Singer and his collaborators during the 1950's entitled *A History of Technology*. Admirable as these volumes are—the Singer volumes being particularly impressive in their detailed coverage—they provide little treatment of social effects. Indeed, the latter is really outside the scope of these works although Singer has one final chapter in volume V entitled " Tech-

nology and Its Social Consequences," written by Sir Alexander Fleck, Chairman of Imperial Chemical Industries Limited.

Major Studies of a Single Subject. Many full-scale studies of specific subjects within the field have also been made. These smaller-scope but important contributions may be exemplified by Wilfred Owen's works concerning the motor vehicle (such as *Automotive Transportation: Trends and Problems*, 1949); William F. Ogburn's major work on aviation (*The Social Effects of Aviation*, 1946); Paul Lazarsfeld's studies of radio listening (such as *Radio Listening in America*, with Patricia Kendall, 1948); Leo Bogart's work on television (*The Age of Television*, 1956 and 1958); the W. F. Ogburn-M. F. Nimkoff work on the influence of technology upon the family (*Technology and the Changing Family*, 1955); the various volumes by Ralph E. Lapp, nuclear physicist, which have contained valuable material on social aspects of nuclear energy including adjusting to the bomb threat; Richard H. Shryock's historical work on medicine (*Development of Modern Medicine*, 1936 and 1947), which ably covers the all-around interplay of medical development and social factors and often indicates social effects; and the late Bernhard J. Stern's studies concerning medical innovations and resistances to them (for example, *Society and Medical Progress*, 1941).

Smaller Research Projects. Although smaller projects, which are generally reported in journal articles, are far too numerous to be listed here, one may at least note clusterings of articles written on certain subjects. In short, some subjects seem to be "amply researched" at the present time; others are relatively neglected.[2] I have found that during the last decade subjects which have been "amply researched" include: social effects of radio and TV; adoption or resistances toward agricultural (farm) innovations; acceptance of or resistance to birth control practice; effects of industrialization in underdeveloped nations; and automation (a reasonable amount on this). Even these subjects undoubtedly warrant far more research activity in the future. Other subjects have been much more neglected, however; I will make comment concerning some of them as we give consideration to possible accomplishments during the future. It is conceded that some subjects present greater research difficulties than others.

Textbooks. In 1941 S. McKee Rosen and Laura Rosen wrote a general textbook in the field entitled *Technology and Society.* With an opening chapter written by Professor W. F. Ogburn this volume described technological developments in five fields—manufacturing, transportation and communication, agriculture, construction, and science—and their economic, social, and political effects. The effects related to the industrialist class, labor, the farmer, urban communities, the family, and the municipal, state, and national governments.

Another general textbook was published in 1957, *Technology and Social Change*, written by a quintet of sociologists—F. R. Allen, Hornell Hart, Delbert C. Miller, W. F. Ogburn, and M. F. Nimkoff. This volume described the process and theories of social change, the social effects of selected inventions (the automobile, motion picture, radio and TV, aviation, and atomic energy), the influence of technology on social institutions (industry, the family, communications and transportation, agriculture, war, and the practice of medicine), provided current discussion of the hypothesis of cultural lag and of problems arising from rapid change, and considered possibilities of planning and control with regard to the nuclear threat.[3]

The Sum of Existing Knowledge. If asked to generalize regarding the kind of knowledge now available, one would be justified in saying the following: First, the guide lines of the field of technology and social change have been set. If the quest for knowledge in this field is likened to the exploration of a continent, one may say that the general outlines of the continent are known. Although much is not known about technology and social change, it is equally correct to say that a great deal (principles, processes, detailed data) is known. The latter includes the processes of invention and diffusion, the principle of cultural acceleration (in the West), the principles of cultural continuity and of cross-fertilization of ideas, the process of causing direct and derivative effects of inventions, the principle of interrelationship of parts of culture, the processes involved in resistance to innovations, the principle that technological change is often basic to other economic and social changes, the principle that the technological influence assumes more importance in modern times than formerly (due to the fact that elements accumulate and are additive), and a consider-

able body of factual data regarding social effects of specific inventions.[4]

However, this existing stock of knowledge does not fulfill to a satisfactory degree the scientific goal of providing systematic generalizations which are consistent with known empirical findings. Sufficient data are still unavailable concerning many subjects, and often the existing data are not theory-oriented. As a consequence some processes or theories are based on much empirical evidence, whereas others have little factual support.

Why data are not yet available on many subjects, even important ones, is illustrated by Lazarsfeld's remarks concerning research on the effects of television on children.[5] The latter is a subject of much current interest since television programs have been thought to be an influence producing, or helping to produce, juvenile delinquency. After citing some research projects on this subject, Lazarsfeld declares:

> But it all adds up to very little, and the work of the various scholars is not coordinated. This is good academic tradition. A professor picks up a topic and sticks with it for a while; but he drops it when something else interests him more or when he can't find a good student to carry out further experiments. . . . We are used to the idea that knowledge on any specific topic accumulates slowly. (p. 244)

Yet he goes on to state that some problems are too important to be left to the "accidental initiative of individual scholars." He discusses the question of funds to finance research and policies of foundations.

> Why has no foundation stepped in and helped to clarify the new role which television is likely to play? There are two reasons for this, one intrinsic to foundation policy, and the other the unfortunate result of an external situation. Foundations have always felt that they should not give prolonged support to any one field. They provide funds for a few years to stimulate a new type of activity; but then they leave it to the universities and professions to go on from there. In general, this policy of discontinuity, so characteristic of foundation grants, makes good sense. But just as in the case of the private scholar, when a topic develops into a social concern a more sustained financing policy might become necessary. (p. 245)

Lazarsfeld's conclusion is that the total situation with respect to television is such that a coordinated and relatively quick build-up of knowledge just has not developed. This conclusion is regarded here as more or less typical of other subjects, too, not something that uniquely applies to television.

In addition to the desirability of accelerating research on many subjects, a further need is to pull together what *is known* and the people who are mutually interested in these subjects. Indeed, this should come first. Research accomplishments in technology and social change are considerable but they are scattered–scattered not only in the sense of being unrelated to systematic theory but in terms of interested people who often represent different disciplines. This lack of communication which has hitherto existed between people interested in the subject of technology and social change can be remedied by the functioning of the Society for the History of Technology.

Accomplishments in Foreign Nations. Since most foreign areas have experienced less technological development than has the United States, social effects from this source there are thus reduced, and the study of this subject tends to be less significant. Indeed, in wide areas of Asia and Africa scholarly work in this field is negligible except for recent studies of industrialization in underdeveloped societies.

On the other hand, both technological development and the study of effects of technology (or industrialization) have been notable in Europe. In Britain and France social scientists, historians, and other writers have tended to emphasize economic history over the years. The Hammonds, Beatrice and Sidney Webb, Clapham, and Samuel Lilley (in his *Men, Machines, and History*, 1948) have emphasized the significance of the Industrial Revolution and the overall impact of the machine age. As noted earlier, the recent *History of Technology* volumes by Charles Singer and his collaborators are significant. The volumes *Man the Maker* (a history of technology and engineering) by R. J. Forbes of Holland and *Mechanization Takes Command* by Siegfried Giedion of Switzerland are ably written and worthwhile, although neither emphasizes social effects.

As examples of works on specific subjects, the volume on automation by Frederick Pollock (economist) of Germany is worthy

of mention. P. M. S. Blackett's *Atomic Weapons and East-West Relations* (1956) and other volumes on nuclear energy provide solid reading. Many shorter studies of television in England and elsewhere, as well as studies of automation and other subjects, have been made. Miscellaneous briefer contributions have been published in the UNESCO journal, *Impact of Science on Society*.

Nevertheless, it is in the United States where the study has led to the greatest results. This is to be expected inasmuch as the study of sociology itself has advanced more in this nation, as has the emphasis on empirical research. Achievements that have been made in other nations have tended to be even more scattered than in the United States.

What Needs to be Accomplished: Suggestions for Research

Outlook. The future study of technology and social change, in my opinion, must be visualized against a world background which has the following elements: (1) a Western world in which applied science and technology have already had an enormous impact and in which expenditures for research and development are increasing –which portends a further increase in the technological influence; (2) a civilization of the East which is characterized by a far lesser, though now increasing, influence of applied science and technology –an area much interested at present in changing to a more industrialized living pattern; (3) a " cold war " world, despite the present thaw, in which the overall United States-Russia struggle is in significant part a technological struggle wherein both sides place marked emphasis and high value on scientific-technological achievement; (4) a world in which the social effects of inventions have already been of tremendous importance (especially in Western civilization) and in which some of the most acute problems, as the nuclear threat, long-range missile threat, and radioactivity, are associated with these effects (some being linked with the " cold war "); and (5) the high probability that as research and development bring further technological advances many more social effects will be produced, including other critical problems. Some of these elements relate largely to the civilian sphere, some are " cold war "-linked, and some are partially associated with the world struggle. Many of the social effects, at any rate, are likely to be of major

importance (some may affect survival). Thus the study of technology and social change is likely to be of basic and increasing significance.

It is hoped that the above reasoning will ring a responsive chord not only from the readers of this journal but also from government and foundation officials and others who may be in a position to aid research on this subject in the years ahead. Past accomplishments, which are impressive and reveal magnificent contributions on the part of some individuals, require additions if they are to keep pace with needs; and, as indicated, future needs are likely to be far greater. In the present situation, random, hit-or-miss research —projects that happen to strike the fancy of individual workers who then execute them as best they can—would seem to be very inadequate. A more organized and coordinated program is required.

Some Suggestions for Research. Topics mentioned here are put forth as samples of what may be done. I do not attempt a lengthy enumeration of possible subjects, not only because space prohibits but because social scientists will use imagination and industry in extending ideas suggested here (and selecting others which are not stated) to settle on meaningful and important subjects. Also, it is clear that research projects may take varied forms—statistical studies, case studies, historical projects, surveys, and the like—hence persons interested in a certain subject may choose their type of study. I suggest the following:

(1) Many new studies may be made of the social effects of so-called "old inventions"—the automobile, motion picture, radio, farm innovations, medical innovations. These subjects are by no means closed. What will be the effects of using the new small-size automobiles? Have changes occurred with respect to social effects caused by the motion picture—with smaller attendance due to TV competition? How many people and what classes of people have been aware of the Salk vaccine for poliomyelitis and have been vaccinated? What is the state of public knowledge with respect to the tranquilizer drugs? To what extent are they used, by what types of people, with what effects?

(2) Very little is known as to social aspects of aviation. What types of people like to fly? Of a total city population sampled, how many people have flown, with what kind of experiences?

How many have never flown? What kind of people began to fly at an early age; made their first flight after many years? Available records show the total number of airline flights per month or year, but many flights might be made by a relatively small number of people (business and professional group). Although sociologists have made many community surveys, I recall no data regarding the number of residents in various communities that have flown—which is likely to be of added interest in connection with space travel. What have been the social effects of such flying? Effects on business, recreation, build-up of distant communities or regions?

(3) Little is known regarding the social effects of nuclear energy. While the new power is being used as a source of electricity in various communities, few studies have been made regarding attitudes toward this use. This is remarkable since problems are related to this use—as concern over the radiation hazard—and community leaders and others might desire such information. C. M. Grigg and I have investigated attitudes of random samplings of both university students and adults in the State of Florida toward the use of nuclear energy. Similar studies are needed in other parts of the United States.

(4) Studies related to destructive uses of nuclear energy are much needed in view of the "cold war" situation and current stock-piling of bombs. What are the attitudes of urban residents toward decentralization and civil defense? Why do many people seem to be apathetic toward the latter? What are the characteristics of those people who are interested in civil defense? What characteristics do the typically-apathetic people have? The Survey Research Center of the University of Michigan conducts annual polls relative to civil defense and has questioned its national population samples regarding many matters, but such questions as the above have often remained unanswered. I have made one study with Florida adults relative to interest in civil defense, but many appropriate studies might be made in different regions and in cities of different size.

(5) With the long-range missile being gradually perfected, how do urban-dwellers view it? Does it affect their reactions toward living in a large city? What sort of people are influenced? Again, little information is available regarding such questions; studies are needed in different regions and in cities of varying size.

(6) Further studies of automation are needed. William Faunce has investigated its effects upon workers and work-relations in an automobile plant. Other studies have been made, but many more studies in different kinds of plants and in offices are needed. Studies of the effects of the use of computers are now receiving more attention.

(7) Many studies of television have been made, but much information regarding social effects is still unknown. What is the cumulative effect of watching TV over the years? What is the process by which "bad" or "harmful" TV programs get on the air? As Lazarsfeld says, studies of the life-history of TV programs are needed: how they are commissioned, how they are written, why they are finally put on the air.

(8) There is need for studies of future effects of inventions which are virtually certain to develop. Use of the helicopter in civilian life is such an invention. Studies of anticipated effects are needed for community planning purposes. Imagination and knowledge of effects of other inventions are needed for this kind of study. W. F. Ogburn, in his *The Social Effects of Aviation*, has contributed ideas and methodology for such studies which attempt to predict in advance.

Some of the above suggestions for research are more difficult than others. Fresh hypotheses to be tested may be derived, moreover, from existing theory. If topics for research are chosen in relation to the theory of a subject—as the theory of the resistances to innovations—this provides the possibility of reformulating or clarifying theory on the basis of the empirical results obtained.[6]

A Final Note on Methodology

Just as contributions of substantive data are needed in the future, so are contributions with respect to methodology. Sometimes the social effects of an invention may be pointed out clearly; in other instances more than one variable is related to some social effect, hence it is most difficult (or impossible at present) to state precisely the effects of some invention. An illustration of this concerns the possible effects of television in causing juvenile delinquency—when other variables as home environment of child, school environment, neighborhood, etc. may also be factors in delinquency. Also,

methodological advances are needed in plotting future effects of a developing invention. The Social Science Research Council has recently shown interest in the study and measurement of social change and has sponsored conferences on the subject. In short, the methods of study as well as the substantive material of technology and social change may be expected to grow in the years ahead.

REFERENCES

[1] This is intended to apply to civilians. It would not apply to military inventions where even the "possible use" of the invention might produce social effects.

[2] I have made a brief tabulation of research conducted on selected subjects in nine journals during the 1949-1958 decade. Six of the journals were in sociology, two in economics, and one in anthropology. I regard this tabulation as a crude measure of current research on these subjects since it is clear that articles on such subjects as television and automation are published in many journals.

[3] Professor Hart, who wrote the chapters on atomic energy, had previously written a bulletin entitled "Social Science and the Atomic Crisis," published as a supplement to the *Journal of Social Issues*, April, 1949; this bulletin won the E. L. Bernays Atomic Energy Award for 1948.

[4] Such principles, processes, and factual material, which cannot be discussed in this short article, are available in textbooks.

[5] Paul F. Lazarsfeld, "Why is So Little Known about the Effects of TV and What can be Done about It," *Public Opinion Quarterly*, XIV, No. 3 (Fall, 1955), 243-251. This was the testimony of Dr. Lazarsfeld before the Kefauver Committee on Juvenile Delinquency. Quotations by permission of Dr. Lazarsfeld and the *Public Opinion Quarterly*.

[6] Robert K. Merton, *Social Theory and Social Structure* (Rev. ed., Glencoe, Illinois, 1957), chaps. 2 and 3.

Methods of Making Chain Mail (14th to 18th Centuries): A Metallographic Note

CYRIL STANLEY SMITH*

METALLOGRAPHY PROVIDES a useful adjunct to historical or archaeological studies. A great deal can be learned from the microstructure of a metallic object about the techniques used in making and treating it. An example is provided by the use of such a method on links of chain mail armor, the manufacture of which has been discussed by Burges [1] and Burgess.[2] Both authors believe that riveted links were made by coiling drawn wire round an appropriate mandrel, cutting to give a series of rings, then overlapping and flattening (perhaps in a die) to give a thickened section through which a rivet hole is drifted with a pointed tool, the rivet being inserted and upset by the use of pliers at the time of assembly of mail. Burgess describes an ingenious set of simple tools which he had devised for the sequence of operations, although he provides no evidence beyond plausibility that they were actually used by makers of mail in earlier times. Some mail is composed entirely of riveted links, but a more usual form is alternate rows of solid and riveted ones. Burges believed that solid links were made by punching from sheet iron with a double punch or by punching a single hole and trimming the outside.

Through the courtesy of Mr. S. V. Grancsay, Curator of Arms and Armor at the Metropolitan Museum of Art in New York, I was able to examine some sixteen links from various suits of armor of known provenance. After superficial examination, the links were sectioned, mounted, polished, and etched following standard metallographic procedures. This permitted the distribution of slag

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inclusions to be seen, as well as local variations of carbon content and heat treatment. The microhardness was also measured. Table 1 describes the links studied and summarizes the findings.

Most of the links are made of soft wrought iron, often containing large amounts of slag. Only three (Nos. 4, 6, and 16, Figs. 5 and 6) contain enough carbon to be classed as steel, and these alone had been given a heat treatment to harden them. Samples of these links were heat treated in my laboratory to give a normalized structure; the microscope then showed that there was a slight gradient in carbon content, decreasing toward the outside of the wire. The links had therefore not been case hardened after they had been shaped, but rather had been made of an initially uniform steel wire which had lost some carbon during the working process. The decarburized areas around rivet holes and other points(appearing white in Figs. 5 and 6) confirm this.[3]

A number of the links contain small amounts of spheroidized iron carbide, indicating that the material had been worked and/or annealed at a temperature below the transformation point but sufficiently high to cause recrystallization and softening of the work-hardened material—perhaps about 700°C. Most of the links show a structure of relatively uniform equiaxed ferrite grains indicating that the rings had been heated after final shaping. A few of them show signs of local cold deformation (probably from unintentional bending or battering), but not one had been left in the cold drawn or rolled condition: all had been annealed after the wire had been made. Two of the Turkish links (Nos. 10 [Fig. 8] and 11) showed some cold deformation which had clearly occurred during the final stamping of the surface inscription, while the third (No. 15) seems to have been hot stamped.

All of the links were made from wire, bent to a circular form and closed by either riveting or welding. The welded links were somewhat less regular in shape than the others, usually flattish in section and often composed of two or three complete turns welded together instead of only a small overlap weld. None of the links had been made by punching or cutting circles of sheet as suggested by Burges,[4] for the streaks of slag or carbon segregation always run circumferentially (Fig. 3). This is hardly surprising, for the manufacture of suitably matched punches and dies would call for a precision of workmanship beyond that of the armorer.

TABLE 1

Ref. No.	MMA Description and No.	Microhardness *	Approx. carbon content **	Remarks
1.	Brayette, German, *ca.* 1525. Riveted links of flat wire; solid, half round. 27.183.14.	155 (143-162)	0.0	Drawn (?) wire, annealed. Round rivet, not headed either end.
2.	Shirt of Mail, German, *ca.* 1500. Solid link, half round wire; riveted link, flat. 29.150.9 v. See Fig. 4.	R 178 (171-180; [238 hard spot])		Slit wire, only slightly drawn, annealed. Rectangular rivet, not tapered.
		S 154 (130-220)	0.0	
3.	Shirt of Mail, German, *ca.* 1500. Riveted link, flat wire; solid, half round. 14.25.2568. See Fig. 2.	R 135 (121-150)	0.0	Same as No. 2.
		S 174 (152-184)		
4.	Shirt of Mail, German, *ca.* 1525. Riveted link, flat wire; solid, half round. 14.25.1555. See Figs. 1, 3, 5, and 12.	R 330 (274-346; [soft areas 147-206]) S 195 (162-265) Four other riveted links had average hardness 462, 461, 446, and 416 respectively in the hard zones with soft spots 168 to 294.	0.5	Drawn wire, ends folded and welded to give thickened part for rivet. Quenched (not above *ca.* 850°C.) and tempered.

5. Shirt of Mail, German, *ca.* 1525. All riveted links (flat wire). 54.46.2.	176 (167-182)	0.2?	Perhaps slightly drawn after slitting. Annealed. Curious structure with both pearlite and spheroidized carbide.
6. Shirt of Mail, German, *ca.* 1550. All riveted links (flat wire). 25.188.9. See Fig. 6.	465 (393-530)	0.6	Drawn wire. High carbon content, hardened by quenching and tempering.
7. Shirt, German, *ca.* 1575. All riveted links (round wire). 29.158.176. See Fig. 13.	198 (184-234)	0.0	Drawn wire, possibly riveted hot but both links and rivet body show some grain distortion.
8. Shirt, German, *ca.* 1575. All riveted links (round wire). 27.237.	153 (137-177)	0.0	Drawn wire. Annealed.
9. Cape, German, *ca.* 1575. All riveted links (round wire). 14.25.1539.	179 (132-222)	0.0	Drawn wire. Very dirty metal. Annealed.
10. Shirt, Turkish, 17th cent. Solid and double riveted links (both flat wire). 36.25.33. See Figs. 7 and 8.	R 148 (137-182) S 196 (181-216)	0-0.15	Poor quality wire, cut from strip or assembled by welding many small pieces. Design cold stamped on to surface of welded link.
11. Shirt, Turkish, 17th cent. Solid and riveted links (moulded section). 14.99.28.	R 138 (129-147) S 224 (207-241)	0.05 0.0	Wire slightly drawn to shape from cut strip. Annealed. Rivet driven cold.

TABLE 1 (Cont.)

Ref. No.	MMA Description and No.	Microhardness *	Approx. carbon content **	Remarks
12.	Shirt, Persian, 18th cent. Solid and riveted links (round wire). 14.25.1562. See Figs. 9 and 14.	S 239 (213-258) R 148 (139-178)	0.0 0.05	Drawn wire. Rivet made of cold drawn wire, not annealed.
13.	Shirt, Persian, 18th cent. All riveted links (round). 36.25.476. See Fig. 10.	125 (91-180)	0.01	Drawn wire, containing many slag inclusions. Annealed.
14.	(Walker's Art Gallery) Coif, European, 14th cent. Round wire, riveted. See Fig. 11.	156 (139-176) 168 (144-202) (2 sections in same link)	0.05	Drawn wire, badly corroded. Deformed metal around rivet shows partial recrystallization, but rivet has distorted structure and was perhaps driven at low red heat.
15.	Shirt, Turkish, 15th cent. Riveted and solid links, flat. 36.25.489 E.	152 (125-194)	0.0	Probably slit wire, raised design struck in heated metal. Many links poorly welded.
16.	Shirt, European, 16th cent. All riveted links. 29.158.3 F.	Four separate links: 243 (226-257) 302 (281-341) 216 (165-337) 168 (143-199)	0.4?	Drawn wire, heat treated to harden. The softest of the four links examined was carbon free, perhaps introduced in a later repair.

* Vickers indenter, 200 gram load. First no. is average hardness from six or more individual impressions, while the numbers in parentheses represent their range. R = riveted links, S = solid links.

** Estimated from structure.

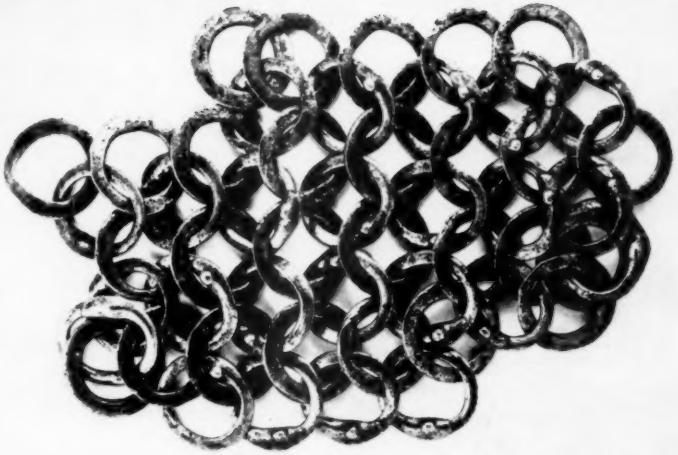


Fig. 1. Portion of assembled mail shirt. (Specimen No. 4, German, *ca.* 1525) × 1.5.

Fig. 2. Two links from shirt No. 3 (German, *ca.* 1500). Both sides of the riveted link are shown. × 5 (*photo reduced 25%*).

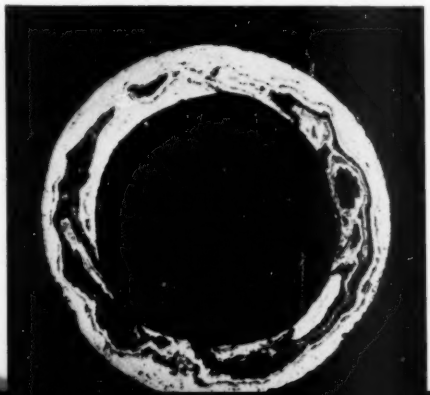


Fig. 3. Plane section beneath surface of welded link from sample No. 4. Etched. × 5.

•• Estimated from structure.

Figs. 4–11. Photomicrographs of cross sections of various links, after etching with 2 percent nitric acid in alcohol to develop the structure.

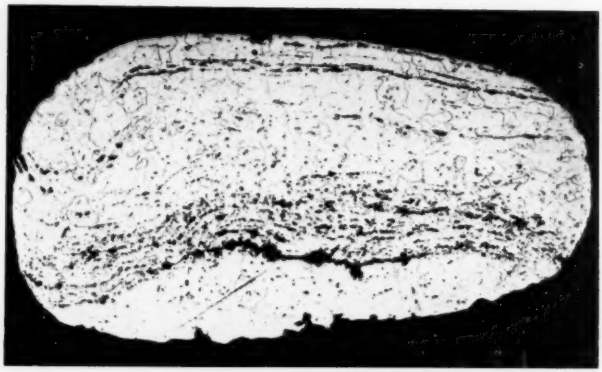


Fig. 4. No. 2-R, × 50 (*photo reduced 30%*).

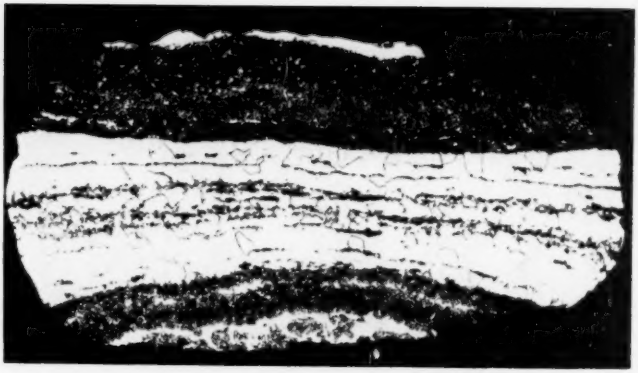


Fig. 5. No. 4-R, × 60 (*photo reduced 30%*). Section near rivet. The structure opposite the rivet was like that of Figure 6.

Fig. 6. No. 6-R, × 75 (*photo reduced 20%*).

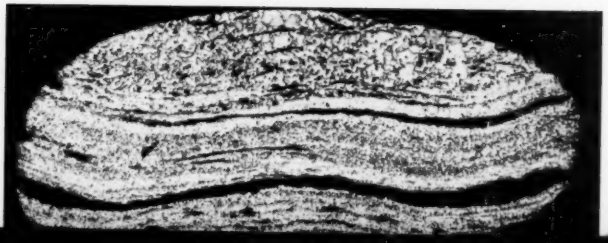


Fig. 7. No. 10-R, × 60 (*photo reduced 35%*).

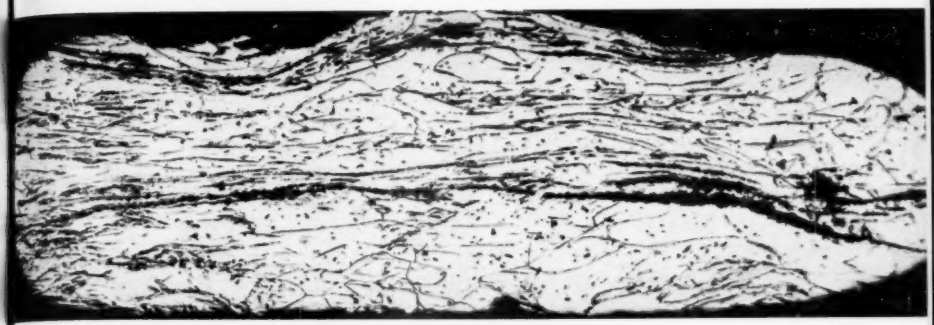
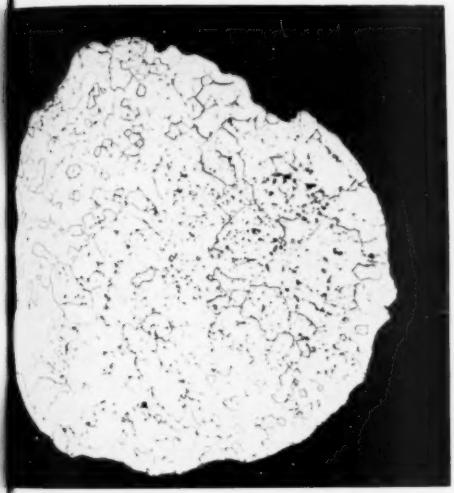


Fig. 8. No. 10-S, × 60 (*photo reduced 5%*).



9. No. 12-R, × 75 (*photo reduced 35%*).

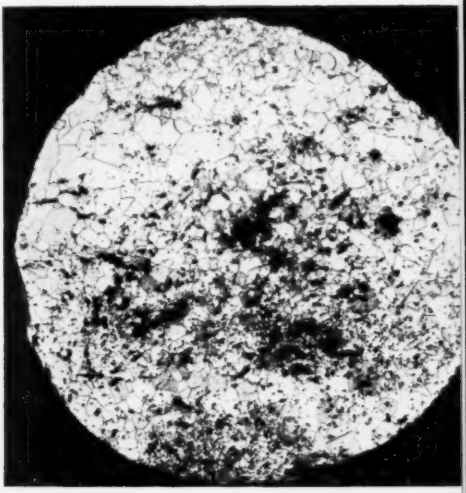


Fig. 10. No. 13, × 75 (*photo reduced 35%*

Fig. 11. No. 14, × 75 (*photo reduced 5%*).

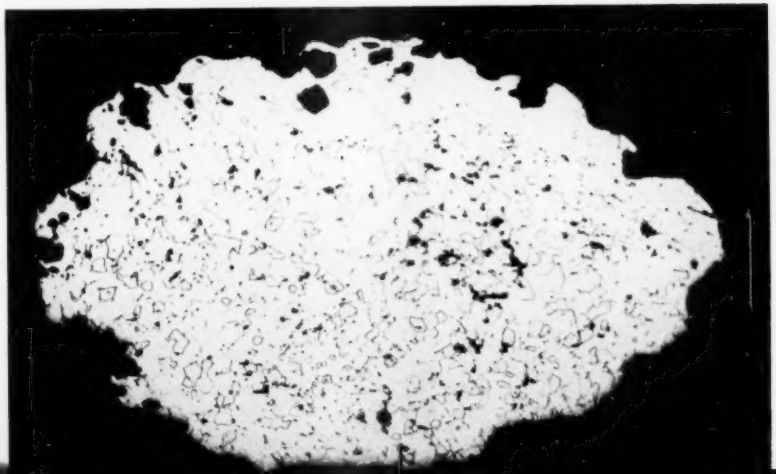


Fig. 12. Cross section through riveted joint in link of shirt No. 4, showing surface decarburization and distortion of metal due to drifting the hole and driving the rivet. Etched. × 50 (*photo reduced 35%*).

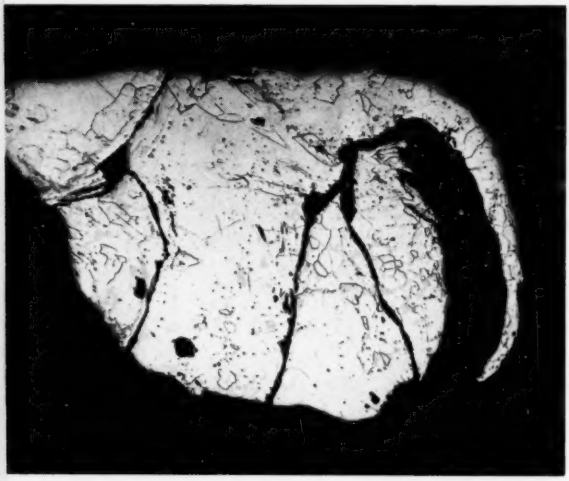
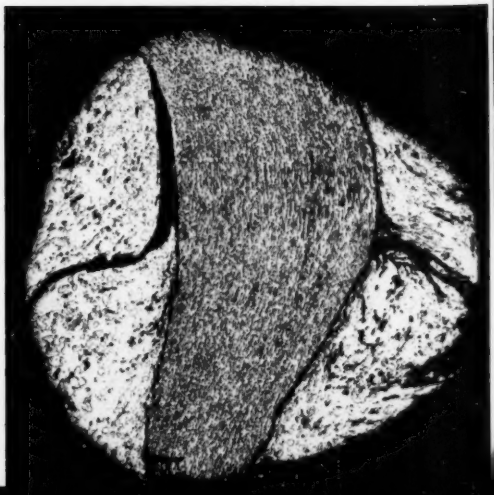


Fig. 13. Cross section through rivet in No. 7. Etched. × 50 (*photo reduced 10%*).



ig. 14. Cross section through rivet in hirt No. 12. × 50 (*photo reduced* 5%). Note the heavily elongated rains in the cold-drawn rivet wire.

The welded links were not finished by forging to their final section but had been partly filed or otherwise cut, as can be judged from the intersection of the present surface with the fibre of the metal. Despite the amount of hand work involved in welding, it was evidently comparable in cost with riveting, otherwise welded links would not have been used so frequently. They would add little to either the strength or the beauty of a suit in which half the links had to be closed by riveting during assembly.

The cross sections of the links normal to the wire axis give some information on the manner of making the wire. Nos. 8, 12, 13, and 14 (Figs. 9, 10, and 11) have a rather uniform distribution of slag and carbide particles such as would result from drawing a wire from a forged rod, maintaining a circular cross section throughout. The Turkish links Nos. 10 (Figs. 7 and 8) and 11 have slag stringers running nearly parallel to each other right across the wire section, and show unmistakably that the wires had been cut from a thin plate or strip and filed, scraped or abraded to the present shape: they are definitely *not* made of die-drawn wire. Even one of the German links (No. 2, Fig. 4) shows very little deformation of a lamellar structure and had probably been only lightly hammered to shape from a slit strip. The other links have an intermediate structure, such as would result if a strip had been cut from a sheet at a larger size (e. g., about 3 to 5 mm. square) and then drawn down to the final section through a relatively small number of dies. This is indeed a logical and likely method of making small-diameter wire from iron and steel in the days before it became possible to hot roll rod in sections small enough for wire drawing.

The rivets are all made of carbon-free iron, even in the hardened steel links. Most of the rivets are of rectangular section and profile, not tapered in either direction, as if they had been cut from strip. The riveting is generally poorly done, and very few of the rivets pass completely through the two pieces to form a good head on both sides: the bulge on the under side is usually composed more of distorted ring than of rivet. Although this would maintain a desirable smoothness on the inside of the mail and would not need a two-stage fitting operation, it would be mechanically weak. In No. 4, the enlarged portion of the ring through which the rivet passed was apparently made by folding back a short length of wire

and welding it to itself and flattening. This was deduced from the local presence of layers of slag and metal of different carbon contents (Fig. 5) which are not present in the wire opposite the joint. One of the Turkish links (No. 15), which bears a heavily stamped design, actually has fake rivet heads. Many of the rings in this shirt are not welded, although overlapping wires are flattened–perhaps just an unintentional result of careless welding at too low a temperature. Some of these links have small copper rivets, apparently added later. The rivet heads on most of the samples are spread out very flatly, suggesting closure with a sharp hammer blow instead of slow pressure, which would cause deep deformation. In one sample (No. 12, Fig. 14) the rivet itself was made of heavily cold-drawn wire. The deformation of the slag streaks in the links in the vicinity of the rivet holes in all the links that were examined shows without doubt that the holes were drifted with a tapered punch, not drilled. The drifting, however, was done hot (or the links were subsequently annealed) for the metal has recrystallized and the grains themselves show little if any deformation. Nos. 3, 4, and 6 show no residual distortion of the grains in the deformed head of the rivet, which therefore must have been driven hot or subsequently annealed. Conversely, however, the contacting surfaces of the rivet and link in most of the others show signs of local deformation which supposedly occurred during the driving of the rivet when cold.

The Turkish links have a design in relief. That this was stamped with a coining die, and not carved or etched, is deduced from the fact that the slag streaks and grains in underlying metal follow the contours of the surface (Fig. 8); moreover, the design is generally more truly circular than the rings themselves.

These findings are in general consistent with the sequence of operations described by Burgess,[5] although they do not prove that the tools he suggests were used. The fact that the wire from which some of the links, both Oriental and European, had been made was not drawn through dies upsets the contention made by Burgess (and by others) that "it is likely that the presence of mail in any civilization proves that the knowledge of wire-drawing was in existence at that time." Though drawing is today the easy and obvious way of making wire, this has not always been so. Whatever may be the situation in regard to the softer non-ferrous metals (which sorely needs critical examination on a metallographic basis)

the making of iron wire by slitting certainly persisted after, and probably preceded by many centuries, the introduction of drawing through dies. Iron is relatively hard, and primitive iron contains slag and scale which quickly destroy any but the hardest die materials, yet it is easy to hammer out a flat sheet and relatively easy to produce sharp cutting surfaces for shears. The presence of longitudinal markings on wire which are often taken as die scratches may be streaks of slag or laminations in the sheet from which the wire was slit.

There is sufficient variation between different links in the same piece of mail to raise some doubt as to the use of even the simple tools suggested by Burgess for shaping them. I incline to the opinion that hand punches and sets were used, except sometimes for the final clinching operation, for which Burgess' pliers would be appropriate. His other tools would be more at home in a nineteenth-century jeweler's shop than in one belonging to a seventeenth-century or earlier maker of chain mail.

The links display regional differences in technique and quality but no evidence of a consistent improvement in metallurgical practice over the period covered. It is remarkable that so few of the links were hardened or even hardenable. Ease of manufacture clearly took precedence over serviceability.

REFERENCES

[1] W. Burges, "Catalogue of the Exhibition of Ancient Helmets and Examples of Mail," *Archaeological Journal*, XXXVII (1880), 455-594.

[2] E. M. Burgess, "The Mail-maker's Technique," *Antiquaries Journal*, XXXIII (1953), 48-55; "Further Research into the Construction of Mail Garments," *Antiquaries Journal*, XXXIII (1953), 193-202; and "The Mail Shirt from Sinigaglia," *Antiquaries Journal*, XXXVII (1957), 199-205.

[3] I believe that the production of steel by long slow heating in carbonaceous material was not a common process before the sixteenth century. Most steel-faced articles could have been made by welding ostensibly uniform steel to an iron substrate. Unfortunately, metallography does not provide incontrovertible evidence, for diffusion occurs during forging and eliminates a sharp interface.

[4] Burges, *op. cit.*

[5] Burgess, *op. cit.*

ACKNOWLEDGMENTS

Mr. S. V. Grancsay started this investigation by raising questions regarding methods of manufacture of chain mail, and he kindly provided the material for study. The skilled metallographic assistance of Mmes. Betty Nielsen and Stanka Jovanovic is gratefully acknowledged. The work was supported in part by the National Science Foundation (Grant NSF-G7574).

What Is a Railway?

JOHN GEISE*

ONE CURIOUS ASPECT of the history of early railways is the failure of most historians to state explicitly what they understand the term "railway" to mean. Moreover, often it is difficult to determine from their writings just what they had in mind on this point. Apparently the majority have felt free to adopt whatever criteria they desired to govern collection of the data on which they base their accounts. As a result, many interpretations of the early development of railways are neither in agreement with each other nor consistent with the facts that can be recovered.

An instance of the difficulties so created is found in the many articles published in 1925 to celebrate the centennial of the Stockton & Darlington Railway, most of which described the achievements of the modern railway in what was termed its first century of operation. As was to have been expected, these articles varied greatly in quality, ranging from trite and misleading statements to valuable summaries and evaluations of a hundred years of well-directed effort. One, published in *L'Écho de Paris*,[1] should probably be placed far down on the scale of value; its author, Charles Foley, after claiming too much credit for France's contributions to the development of the railway, devoted the greater part of his discussion to the way steam locomotives, puffing through the countryside, had revived ancient superstitions about the devil and his works. Foley's chitchat reached its low point in his identification of Huntingdon Beaumont, who was reported as having introduced *chemins à rails de bois parallèles* into Tyneside in 1630; on the strength of the name "Beaumont," this son of an old Leicestershire family was claimed as a Frenchman.

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Certainly there was little in this article to recommend it for serious study, yet it has been cited a number of times by outstanding students of British economic history. Moreover, it became the vehicle for a discerning observation on the origins of the railway.

To Nef, the historian of the early British coal trade, Foley's article suggested the comment that the steam railway, as evolved in Great Britain during the first half of the nineteenth century, represented a happy combination of two much earlier developments of the British mining industry: the wagonway, for the cheap transportation of coal overland, and the steam engine, for draining water from mines quickly and economically.[2]

Nef's comment indicated that the development of the modern steam railway had begun long before the Stockton & Darlington Railway was opened. On the other hand, most of the historians of British railways have tacitly assumed that for all practical purposes it started with the passage of the Surrey Iron Railway Company's enabling act,[3] which antedated the opening of the Stockton & Darlington Railway by only twenty-four years. The latter viewpoint certainly does not suggest the significant fact that in June 1799, because of the increasing number of petitions for leave to bring in railway bills that were being received, the House of Commons had adopted a special set of Standing Orders to govern the progress of legislation conferring powers to construct railways.[4] Nor does it recognize the further fact that the enabling act for the Surrey Iron Railway [5] was the seventy-eighth act conferring railway powers that had been passed into law since legislation for this purpose had first been introduced in 1753.[6]

The discrepancy between the view that the railway is a nineteenth-century development beginning with the Surrey Iron Railway's enabling act, on the one hand, and the information that is available about an active demand throughout the second half of the eighteenth century for legislation authorizing railway construction, on the other, suggests the possibility that the historians of the early railway have not faced the problem of what really constitutes a railway. There can be no doubt of this, but the point is so significant as to deserve further demonstration of the principle involved.

In working out the history of a technical device or a technical

system, a clearly-stated definition of the subject to be investigated is much more necessary than in many other fields of historical research. The reasons for this have already been suggested, but they can be underscored by discussion of the effects on historical research and writing of failure to define precisely a technical subject which is to be investigated. For this purpose, I will use Lewin's *Early British Railways*—an admirable and useful compendium of information about the lines authorized by Parliament before 1845.[7] By way of preface, criticisms of this work are made only to demonstrate what is believed to be an important point about the writing of railway history. They are advanced in that spirit, with apologies to Mr. Lewin for treating a good work so poorly.

The title, *Early British Railways: A Short History of Their Origin & Development, 1801-1844*, suggests that the volume covers the history of all British railways for the period named. Actually, the text covers that period, but only for railways that received powers from Parliament, and not for all of them. On the other hand, when it came to compiling a statistical table from which generalizations about railway development in this period could be drawn, Lewin did not go back before 1821, the year of the enabling act of the Stockholm & Darlington Railway. This he justified by stating that the lines authorized before 1821 were "small local lines to be worked by horse power in various parts of the kingdom. . . ." [8]

Lewin's decision to exclude from his statistical summary (which has been used quite extensively by later historians) the lines authorized before 1821 does not appear to have been sound, and certainly it is not justified by the reasons he gave for it. In the first place, although the average length of the sixteen lines authorized in 1801-1820 and eventually opened was only 13.63 miles, as against an average of 16.88 miles for the ten lines authorized in 1821-1825 and opened, the distribution of these two groups of railways by length shows a close correspondence between the activities of the two periods:

Length of Line	Number of Lines 1801-1820	1821-1825
6-10 miles	7	4
11-15 "	3	1
16-20 "	2	2
21-25 "	3	1
26-30 "	1	0
31-35 "	0	2

This distribution, together with the really small difference between the average lengths of line for the two periods, would argue against exclusion of the earlier lines on the grounds of length alone.

According to Lewin, three of the lines sanctioned in 1801-1820 were converted to steam before 1850, and ten in all were eventually changed over from horse power to steam traction. When it is noted that eight of the ten lines authorized in 1821-1825 were originally worked by horse power, in whole or in part, the exclusion of the pre-1821 lines from a statistical summary because at first they were worked by horse power does not seem reasonable.

The problem can also be approached by reference to the roles the various lines authorized before 1821 played in Britain's internal communications during the period covered by Lewin's work. This is no place for a detailed discussion of this subject, but the end desired can be served by quoting Jackman's excellent reworking of Cumming's comments on the Sirhowy Railway, the enabling Act for which was passed on 26 June 1802:

> The history of the great Sirhowy Tramway, in the county of Monmouth, may enable us to see more clearly the relation of these early roads to the country through which they passed; and we have chosen this one because, in point of magnitude, it was one of the greatest. It extended from Pilgwelly, near Newport, to the Sirhowy and Tredegar Iron Works (24 miles), whence it was continued five miles further to the Trevil Iron Works, in Brecknockshire, along with a branch westward to the Rumney and Union iron works. This railway was constructed at the suggestion of Mr. Outram. On being consulted by the Monmouthshire Canal Company, as to the best means of supplying that canal with water, of which there was such a great shortage that trade was suffering severely, Outram recommended a few reservoirs to be made, but more particularly a tramroad, to run parallel with the Crumlin line for eight or ten miles out from the town of Newport. In order to ease or take away part of the trade from the canal, this line was to pass through Tredegar Park, the property of Sir Charles Morgan; and it was finally arranged between Sir Charles, the Monmouthshire Canal Co., and the Tredegar Iron Works Co., that he should make one mile, which was in his park, the Monmouthshire Canal Company was to make eight miles, and the Tredegar Iron Works Company to make the remaining fifteen miles, each to take tonnage on its respective part of the road. The road was completed about 1804, and also a turnpike by the side of it for about seventeen miles, at a total cost of about £74,000,

> or about £3,000 per mile. . . . Notwithstanding this expense, this road in 1824, paid the proprietors thirty per cent., by reason of having a considerable trade upon it in coal and iron, which paid the same tonnage as upon the canal. For the first nine miles out of Newport (the parts made by the Canal Company and Sir Charles Morgan) it was a double road: one for the loaded waggons to come down, and the other for the empty ones to return; and on the Tredegar Iron Company's part (fifteen miles) it was a single road, with frequent places to turn out and pass.[9]

Even if we disregard the conversion of the Sirhowy Railway to steam traction, which was begun in 1829, and the eventual absorption of the enterprise by the London & North Western Railway in 1860, after more than a half-century of successful and profitable operation, this line clearly should not be omitted from a statistical analysis of early nineteenth century British railways. Quite a number of other railways sanctioned before 1821 have similar claims to recognition.

Thus on three grounds–length of line, type of traction employed, and contribution to Britain's expanding system of internal communications–there seems to have been no good reason for excluding the activities and accomplishments of 1801-1821 from a statistical summary of the early growth of British railways. Yet, if this is so, why did Lewin omit them? Inasmuch as there can be no question of his demonstrated ability as a researcher, the most likely answer is that he probably did not give serious thought to the question of what a railway really was in the early decades of the nineteenth century.

Careful examination of *Early British Railways* indicates that Lewin employed three criteria in selecting the railways to be included in his work. They appear to have been as follows:

1. Authorization of a line by Parliament.
2. Line to be open to the public on the payment of specified charges.
3. Line to be operated by a company specifically organized for that purpose only.

The first two seem to be sound and, applied uniformly, should yield a list of most of the major railways opened in Great Britain between 1801 and 1844. As regards the third, there would seem

to be no valid a priori reason for differentiating between a railway owned and operated by a separate company and one owned and operated by a company which was also engaged in some other type of enterprise. Granted a possible difference of general policy as between the two, if this difference were kept in mind wherever found, it would be entirely possible to trace the growth of all lines and determine the influence each exerted on the development of the railway system as a whole. From this viewpoint, Lewin's omission of the public railways operated by companies that were not exclusively railway companies is difficult to justify. An example will strengthen this point.

The Liverpool & Manchester Railway, which was built under an enabling act of 1826 and two amending acts passed in 1827-1829, is recognized as the most influential of the early public railways and is adequately dealt with as such by Lewin. But the Trent & Mersey Canal Company's Froghall & Caldon Railway, in Staffordshire, which was built and relaid under acts of 1776 and 1783 and was entirely rebuilt under an act of 1802, is not to be found in Lewin's list of public railways. That one of these lines was constructed and operated by a railway company and the other by a canal company, would seem to have little bearing on the problem of tracing the development of the British public railway system; both lines were part of it.[10] The Trent & Mersey Canal Company's act of 1802 provided for the relaying of the Froghall & Caldon line as an edge railway, and the work called for was very well done by Rennie;[11] the result was an up-to-date line of railway which served satisfactorily until 1849, when it was again rebuilt. The act of 1802 also authorized the Canal Company to construct three additional lines of railway in the pottery district, to serve "the extensive manufactories of earthenware established at those places, and to be of great public utility." Most important of all, the act of 1776 had authorized the Company to collect tonnage on all goods, wares, and commodities carried on their railway as well as on their canal, and the act of 1802 more specifically authorized the Company to collect tonnage on all "waggons and carriages, of forms and construction, and with burthens suitable to such railways" as it might approve for use on its lines.

Thus two railways, selected at random from the periods 1801-1820 and 1821-1830, were given diametrically opposite treatment

by Lewin; the later one received full attention, the earlier was completely disregarded. As has been said, the only identifiable basis for this difference in handling is that the line omitted was owned and operated by a canal company. That both lines were authorized by Parliament to operate as public railways—and in fact did so operate—apparently had no influence on Lewin's exclusion of the Froghall & Caldon from his study. He permitted his third criterion for the selection of data to override the other two—and this is generally characteristic of his work as a whole.

Thus all the evidence that can be adduced from Lewin's account of early British railways supports the conclusion that he did not satisfactorily answer the question, "What is a railway?" The result has been a distinct limiting of the usefulness and value of an otherwise excellent study.

I have made these observations to show the extent to which one of the best of the available histories of early British railways has fallen short of its mark as a result of the author's failure clearly to define its scope. The major positive conclusion to be drawn from the analysis is that, historically viewed, a railway is something more than an individual commercial enterprise authorized for public use by a governmental agency and operated by a company devoted exclusively to this enterprise.

As has been said, in only a very few of the many histories of British (and other) railways has there been found an attempt to define what actually constitutes a railway. Possibly the outstanding exception is in Lee's introduction to his second study of the Surrey Iron Railway:

> The public railway . . . provides an outstanding example of a combination of engineering appliances, both civil and mechanical. Broadly, the modern railway may be regarded as a combination of four main factors, namely, (a) specialised track; (b) accommodation for public traffic; (c) conveyance of passengers; and (d) mechanical traction.[12]

The usefulness of such a definition in providing historical perspective is attested by the foreword to another of Lee's studies of early British railways, written two years after his first statement was put down and, in effect, an application of it:

> The public railway, as we know it today, provides an outstanding example of a combination of engineering principles, both

civil and mechanical, all of which were known long before they were applied generally to the improvement of transport. Broadly, the modern railway may be regarded as a combination of four such features, namely, (a) specialised track; (b) accommodation of public traffic; (c) conveyance of passengers; and (d) mechanical traction. The use of specialised track to facilitate the movement of heavy loads is of considerable antiquity, . . . and railways have been an adjunct of the mining industry in the North and Midlands of Great Britain since the time of Queen Elizabeth; they were private concerns, reserved for the exclusive use of their owners, and intended chiefly to convey coal from the pit mouth to the waterside. Thus we may date the use of specialised track, even in England, as far back as 1597. The accommodation of public traffic on rail developed to a limited extent during the fourth quarter of the eighteenth century as railway branches were built to feed canals, chiefly through hilly country. The first public railway sanctioned by Parliament, independent of a canal, was the Surrey Iron Railway, and the incorporation of the Surrey Iron Railway Company on May 21, 1801 . . . marked the beginning of a new and important era, introducing the second characteristic of the modern railway, namely, the accommodation of the traffic offered by all comers without discrimination.

Conveyance of passengers was first undertaken on the Oystermouth Railway or Tramroad on March 25, 1807, as a service provided by a private contractor paying tolls to the owning company. . . . Regular mechanical traction was begun, on August 12, 1812, on the Leeds Middleton Railway—largely as a result of the high cost of animal feed during the Napoleonic Wars—and thus all the main features of the modern railway were in use in 1812, but separately and not in combination. . . . It was not until the formal opening of the Liverpool & Manchester Railway on September 15, 1830, that the modern conception of the railway, as a public service on rail by mechanical traction, was realized.[13]

This concept of the development of railways, obtained by applying to research an analysis of the elements comprising a railway, stands in strong contrast to the interpretation implicit in a work such as Lewin's. Note, for example, how Lee's procedure saved him from repeating the error made by George MacLaren in 1824 when he wrote, "Railways are much more recent inventions than canals," [14] an error which has colored the views of many writers since it was published.

Having thus presented the problem of definition, I should make an attempt to resolve it. As a step in this direction, I suggest that

the railway can basically be regarded as a combination of technical devices and specialized personnel which is designed to provide overland transportation of freight and passengers according to established schedules and at specified standard rates. However, it should at once be noted that not all of the railway's characteristics were developed and put into effect at the same time. On the technical side, for example, the track of parallel rails of a given gauge, suitably laid on a prepared roadbed, was introduced very early (in the closing years of the sixteenth century), but the steam locomotive did not appear until after Trevithick's experiments at the beginning of the nineteenth century. The nontechnical characteristics of the railway show the same sequential traits.

What is needed is a study of the development of the railway to determine not only what its principal characteristics as a historical phenomenon have been but also when each appeared. Such an analysis, which would follow the lines suggested by Charles Lee, would go beyond the purpose of this paper, which is to state the problem. Worked out in some detail, its findings will throw valuable light on the chronological pattern of railway history.

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[3] C. F. Dendy Marshall and Charles E. Lee are the most prominent exceptions to this statement; among the economic historians whose interests include the development of railways, W. T. Jackman and J. H. Clapham give considerable attention to the pre-1801 steps which led up to the steam railway.

[4] *Journals of the House of Commons*, 54 (1798-1799), 689.

[5] 41 Geo. 3, c. xxxiii, An Act for making and maintaining a Railway from the Town of *Wandsworth* to the Town of *Croydon*, with a Collateral Branch into the Parish of *Carshalton*, and a Navigable Communication between the River *Thames* and the said Railway at *Wandsworth*, all in the County of *Surrey*. 21 May 1801.

[6] *CJ*, 25-56, *passim*. The first act authorizing the construction of railways was 26 Geo. 2, c. xxxv, the fourth amending act for the River Dee Navigation, which received the royal assent on 15 May 1753. The first act authorizing the construction of a railway separate from a river navigation was 31 Geo. 2, c. xxii, the enabling act for the Leeds (Middleton) Wagonway, which became law on 9 June 1758; this, of course, antedated the passage of the enabling act for the Duke of Bridgewater's Canal, which marked the beginning of Britain's canal age. Incidentally, the Leeds Wagonway was the railway on which John Blenkinsop introduced the rack-and-pinion locomotive in 1812.

[7] H. G. Lewin, *Early British Railways: A Short History of Their Origin & Development, 1804-1844* (London, Locomotive Publishing, 1925). Organized in terms of Parliamentary action and drawing heavily on Parliamentary records, this volume and its sequel, *The Railway Mania and Its Aftermath, 1845-1852* (London, Railway Gazette, 1936), filled what had been a serious gap in the studies of British railways of the first half of the nineteenth century.

[8] *Ibid.*, p. 8. Incidentally, in his text Lewin lists twenty different railways as having been authorized by Parliament in 1801-1820, and states that only sixteen of them were ever constructed; he furnishes "brief particulars" about thirteen of these sixteen. One of the thirteen, in time converted to steam and then to electric traction, was still in operation as an independent company when Lewin published in 1925.

[9] W. T. Jackman, *The Development of Transportation in Modern England* (2 vols., Cambridge, 1916), II, 471n, as reworked from T. G. Cumming, *Illustrations of the Origins and Progress of Rail and Tram Roads . . .* (Denbigh, 1824), pp. 45-46. By permission of the executors of the William T. Jackman Estate and the Cambridge University Press.

[10] Lewin's exclusion of the Froghall & Caldon Railway is all the more indefensible when contrasted with his inclusion (in his text, not in his statistical tabulation) of the Sirhowy Railway, in whose construction and operation the Monmouthshire Canal Company, to say nothing of the Sirhowy and the Tredegar Iron Works, played a major part.

[11] Charles E. Lee, *The Evolution of Railways* (London, 1937), pp. 38-39.

[12] Charles E. Lee, *Early Railways in Surrey: The Surrey Iron Railway and Its Continuation the Croydon, Merstham and Godstone Railway (A Paper Presented to the Newcomen Society on December 11, 1940)* (London, 1944), p. 3.

[13] Charles E. Lee, *The First Passenger Railway (The Oystermouth or Swansea & Mumbles Line)* (London, 1942), pp. 3-4. By permission of the Tothill Press, Ltd.

[14] George MacLaren, *Railways Compared With Canals and Roads . . .* (London, 1825), as reprinted in *The Pamphleteer*, XXVI (1825), 59.

Sullivan's Skyscrapers as the Expression of Nineteenth Century Technology

CARL W. CONDIT*

IT IS NOW A matter of common consent that Louis Sullivan (1856-1924) was the first great modern architect, the first to create a new and powerful vocabulary of forms derived from the major cultural determinants of his age. He was the most imaginative and the most articulate figure among a small group of creative men in Europe and America who, suddenly around 1890, struck out in a new direction with the deliberate intention of breaking once and for all with the traditional architectural forms of the classical and medieval heritage. In Europe the movement called itself *Art Nouveau*, its initiator being the Belgian architect Baron Victor Horta (1861-1947). In the United States it was at first confined largely to Chicago, where the fire of 1871 prepared the way for one of the most exuberant outbursts of creative activity in nineteenth century architecture. The leadership of this movement, now known as the Chicago school, was initially in the hands of William Le Baron Jenney (1832-1906), but by 1890 it had passed to Sullivan and his engineering partner, Dankmar Adler (1844-1900). Within a single decade Adler and Sullivan moved rapidly, if irregularly, from close dependence on past architectural styles to an organic form which derived its character from the industrial and scientific culture which had swept everything before it in the Western world.

By the last decade of the century Sullivan had developed in preliminary terms his organic theory of building art, a system which was later to be presented at length in his major writings, *Kindergarten Chats* (1901-1902) and *The Autobiography of an*

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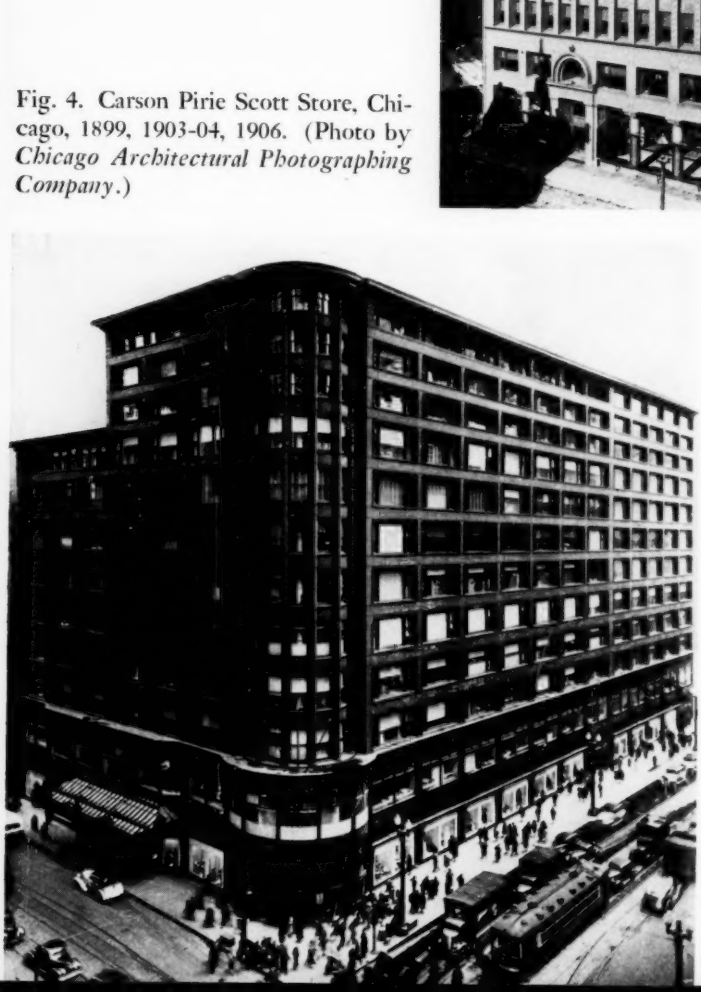
Fig. 1. Auditorium Building, Chicago, 1887-89. The building is now owned by and houses the facilities of Roosevelt University. (Photo by *Chicago Architectural Photographing Company*.)

Fig. 2. Wainwright Building, St. Louis, Missouri, 1890-91. (Photo by *Keystone View Company*.)

Fig. 3. Prudential, formerly Guaranty, Building, Buffalo, New York, 1894-95. (Photo by *Chicago Architectural Photographing Company*.)

Fig. 4. Carson Pirie Scott Store, Chicago, 1899, 1903-04, 1906. (Photo by *Chicago Architectural Photographing Company*.)



Idea (1922). The philosophy of architecture offered in these works contains extensive ethical and social elements as well as formal and aesthetic. Since the doctrine has been discussed, analyzed, and interpreted in detail by historians and critics, we need not here inquire into it at length. Our purpose is to find, if we can, the broad symbolic meaning of Sullivan's major works, for which it may be useful to summarize some of the fundamental ideas in his system of thought.

Sullivan's interest in structural engineering—in part, of course, the product of professional necessity—early developed into a wide-ranging enthusiasm for science as a whole. It centered mainly in biology, from which his organic theory in part stemmed, but it included the new physical theories as well. He read Darwin, Huxley, Spencer, and Tyndall at length and was well acquainted with the writers who were then developing the seminal theories of building art in the past century, chiefly Ruskin, Morris, and Viollet-le-Duc. What distinguishes Sullivan's thought is his profound grasp of the social basis, the responsibility, and the problem of the arts in a technical and industrial society. He felt that he had discovered the rule with no exceptions (to use his own phrase) in the concept "form follows function," but the key to his philosophy lies in the proper understanding of the word *function*. An organic architecture, he believed, is one which grows naturally or organically out of the social and technical factors among which the architect lives and with which he must work. These factors embrace not only the technical and utilitarian problems of building but also the aspirations, ideals, and needs, both material and psychological, of mankind. Thus *functionalism* involved for him something much wider and deeper than utilitarian and structural considerations, as important as these are.

To Sullivan the creation of a genuine architectural style was not a matter of historical styles or of dipping into a vocabulary of contemporary forms and details in order to secure a style which the architect might feel to be consonant with the life of his time. The architect must first recognize the importance of true aesthetic expression for the symbolic recreation, the harmonization, and the emotional enrichment of the many practical and intellectual elements of contemporary civilization. In European and American society at the end of the nineteenth century such an art would

begin, by necessity, with the fundamentals: industry, technology, and science. It is the task of the architect, as Sullivan conceived it, to take the products of techniques, on the one hand, and the logic and order of a scientific technology, on the other, and mold them into a form uniting both in a single aesthetic expression. An architecture so developed means the humanization through aesthetic statement of the often cold and non-human facts of industrial techniques.

The early application of this complex philosophy of the organic to a specific building problem appeared in a document which has become a classic of modern theory, "The Tall Office Building Artistically Considered," first published in *Lippincott's Magazine* in 1896. Scattered throughout *The Autobiography of an Idea*, which is Sullivan's final testament, are many sentences of an epigrammatic character that summarize his thought; for example, "As the people are within, so the buildings are without," or again, "It is the task of the architect to build, to express the life of his own people."

The realization of this program in actual commissions reached its mature form in the four largest and most impressive buildings which Adler and Sullivan designed. The first is the Auditorium Building, now Roosevelt University in Chicago, designed in 1886-1887 and opened in 1889. (Fig. 1) The design of this great building, with its huge masonry bearing walls, was much influenced by Richardson (1838-86) and the Romanesque-like forms which he handled so brilliantly. But it marks a transition toward the open and dynamic wall forms that were soon to become the distinguishing feature of Sullivan's work. In the year following the completion of the Auditorium he struck out in a new direction to produce one of the most remarkable exhibitions of sheer architectural originality in his own or any age, the steel-framed Wainwright Building in St. Louis (1890-91). (Fig. 2) A few years later the formal character of this structure was refined and enriched in the Guaranty, later Prudential, Building in Buffalo (1894-95). (Fig. 3) In the last of his large commissions, before the poverty and neglect of his later years, he turned in still another direction and produced a radically different kind of expression in the Carson Pirie Scott Store in Chicago, built in three parts over the years from 1899 to 1906, although designed as early as 1896. (Fig. 4)

Behind these steel-framed buildings lay a long preparation in the history of iron construction. The use of iron as a structural material goes back to classical antiquity, but it did not appear wholly emancipated from masonry until the construction of Darby and Pritchard's cast iron arch over the River Severn at Coalbrookdale, England, in 1775-79. The first building with interior columns and beams of iron was William Strutt's Calico Mill at Derby (1793). It was thirty-five years before iron members appeared in American buildings and 1850 before complete iron construction was established, largely through the work of the New York inventors and builders Daniel Badger and James Bogardus. The remainder of the century saw steady progress in the techniques of cast and wrought iron and later steel framing, reaching its culmination in the skyscrapers of New York and Chicago, in which all the essential features of the modern commercial building were given a practical demonstration.

Thus, by 1890, the technical means of a new building art were available to Sullivan. It remained for him to transmute the structural solutions to these unprecedented functional requirements into a symbolic art. His organic philosophy had already come to exist at least in an inchoate form, but so broad an aproach to architectural design could not lead directly to a specific kind of formal expression. The key to the process of transmutation may be found, I think, in those passages of Sullivan's writings in which he gives voice to his feelings about particular architectural and structural achievements of his age. We have already mentioned his debt to Richardson. There is a chapter in *Kindergarten Chats*—Number VI, "The Oasis"—in which he acknowledges this debt, and it is the first of various passages that lead us to an understanding of Sullivan's inner purpose. He describes for us, in ironic and impressionistic metaphors, his strong emotional reaction to Richardson's Marshall Field Wholesale Store in Chicago (1885-87) and to what it stands for.

> Let us pause, my son, at this oasis in our desert. Let us rest awhile beneath its cool and satisfying calm, and drink a little at this wayside spring. . . .
>
> You mean, I suppose, that here is a good piece of architecture for me to look at—and I quite agree with you.
>
> No; I mean here is a *man* for you to look at. A man that walks

> on two legs instead of four, has active muscles, heart, lungs, and other viscera; a man that lives and breathes, that has red blood; a real man, a manly man; a virile force—broad, vigorous and with a whelm of energy—an entire male.
>
> I mean that stone and mortar, here, spring into life, and are no more material and sordid things, but, as it were, become the very diapason of a mind rich-stored with harmony. . . .
>
> Four square and brown, it stands, in physical fact, a monument to trade, to the organized commercial spirit, to the power and progress of the age, to the strength and resource of individuality and force of character; spiritually, it stands as the index of a mind, large enough, courageous enough to cope with these things, master them, absorb them and give them forth again, impressed with the stamp of large and forceful personality; artistically, it stands as the creation of one who knows well how to choose his words, who has somewhat to say and says it—and says it as the outpouring of a copious, direct, large and simple mind.[1]

It is clear that Sullivan was profoundly moved by Richardson's building, but even a fine work of architecture did not arouse in him the powerful emotions that were evoked by the great achievements of the bridge engineers in the nineteenth century. There are several illuminating passages in *The Autobiography*, among the most remarkable in the book, in which he tries to analyze his emotional and philosophic response to these monuments of pure structural form. The first records a childhood experience in which he saw a chain suspension bridge over the Merrimack River (possibly Finley's Bridge of 1810, near Newburyport, Massachusetts). The description is loaded with the most extreme expressions of feeling.

> Mechanically he ascended a hill . . . musing, as he went, upon the great river Merrimac. . . . Meanwhile something large, something dark was approaching unperceived; something ominous, something sinister that silently aroused him to a sense of its presence. . . . The dark thing came ever nearer, nearer in the stillness, became broader, looming, and then it changed itself into full view—an enormous terrifying mass that overhung the broad river from bank to bank. . . .
>
> He saw great iron chains hanging in the air. How could iron chains hang in the air? He thought of Julia's fairy tales and what giants did. . . . And then he saw a long flat thing under the chains; and this thing too seemed to float in the air; and then he saw two great stone towers taller than the trees. Could these be giants?

. . . [A page follows in which Sullivan records how he ran frightened to his father to tell him that the giants would eat him.]

So [his father] explained that the roadway of the bridge was just like any other road, only it was held up over the river by the big iron chains; that the big iron chains did not float in the air but were held up by the stone towers over the top of which they passed and were anchored firmly into the ground at each end beyond the towers; that the road-bed was hung to the chains so it would not fall into the river. . . . On their way to rejoin Mama, the child turned backward to gaze in awe and love upon the great suspension bridge. There, again, it hung in the air—beautiful in power. The sweep of the chains so lovely, the roadway barely touching the banks. And to think it was made by men! How great must men be, how wonderful; how powerful, that they could make such a bridge; and again he worshipped the worker.[2]

In later years, on his way to becoming an established architect in partnership with one of the great building engineers of his time, Sullivan came to understand how these miracles were accomplished. Then he was prepared to pay his fullest tribute to the bridge engineers and to record it again in his *Autobiography*.

About this time two great engineering works were under way. One, the triple arch bridge to cross the Mississippi at St. Louis, Capt. Eades [*sic*], chief engineer; the other, the great cantilever bridge which was to cross the chasm of the Kentucky River, C. Shaler Smith, chief engineer, destined for the use of the Cincinnati Southern Railroad. In these two growing structures Louis's soul became immersed. In them he lived. Were they not his bridges? Surely they were his bridges. In the pages of the *Railway Gazette* he saw them born, he watched them grow. Week by week he grew with them. Here was Romance, here again was man, the great adventurer, daring to think, daring to have faith, daring to do. Here again was to be set forth to view man in his power to create beneficently. Here were two ideas differing in kind. Each was emerging from a brain, each was to find realization. One bridge was to cross a great river, to form the portal of a great city, to be sensational and architectonic. The other was to take form in the wilderness, and abide there; a work of science without concession. Louis followed every detail of design, every measurement; every operation as the two works progressed from the sinking of the caissons in the bed of the Mississippi, and the start in the wild of the initial cantilevers from the face of the cliff. He followed each, with the intensity of personal identification, to the finale of each. Every difficulty he encountered he felt to be his own; every expedient, every device, he shared in. The chief engineers became

> his heroes; they loomed above other men. The positive quality of their minds agreed with the aggressive quality of his own. In childhood his idols had been the big strong men who *did* things. Later on he had begun to feel the greater power of men who could *think* things; later the expansive power of men who could *imagine* things; and at last he began to recognize as dominant the will of the Creative Dreamer: he who possessed the power of vision needed to harness Imagination, to harness the intellect, to make science do his will, to make the emotions serve him—for without emotion—nothing.[3]

There is a distinct strain of romanticism in this passionate devotion to the builder, perhaps even a Nietzschean quality in the worship of creative power. For Sullivan came to see in science and technology the triumphant assertion of man's will expressing itself in a wholly new way. As he himself put it, "Louis saw power everywhere; and as he grew on through his boyhood, and through the passage to manhood, and to manhood itself, he began to see the powers of nature and the powers of man coalesce in his vision into an IDEA *of power*. Then and only then he became aware that this idea was a *new idea*,—a complete reversal and inversion of the commonly accepted intellectual and theological concept of the nature of man." [4]

Thus Sullivan conceived of a bridge as the personal testament of a man, a testament expressing a unification of the highest energies and skills of the age. What distinguishes these achievements is not only the technical virtuosity that men like Eads and Smith commanded, but the integration of many streams of technical and scientific progress in the nineteenth century. For it was the age that saw the transformation of building from an empirical and pragmatic technique into an exact science. Since Sullivan chose the St. Louis and Dixville bridges as his examples, we may use them as representatives of the transformation that made possible their design and construction. Eads Bridge (1868-74) is the earlier of the two, and so we may begin with an analysis which reveals how such structures brought to focus the various scientific and technical currents.

The general staff of Eads Bridge consisted of James B. Eads as chief engineer, Charles Pfeiffer and Henry Flad as principal assistants, and William Chauvenet, Chancellor of Washington University, as mathematical consultant. The choice of Eads, who had

never built a bridge before, as head of the St. Louis project rested in large part on his intimate knowledge of the river. For the builder who proposed to found his piers on the rock far below its bed, it was a formidable obstacle indeed. The pilots could read its surface with remarkable skill for the hidden snags and bars that once menaced them, but only Eads knew at first hand its fluid, shifting, treacherous bed. By means of the diving bell which he had invented, he was able to investigate the bottom directly, and he had seen its depth change from 20 to 100 feet at obstacles in the bed as the result of the scouring action of currents. For the first time the topographic and geological surveys of the bridge site could be carried on to a certain extent under water.

With the design of his bridge substantially completed and sufficient capital available, Eads began clearing the site and constructing caissons in the summer of 1867, but difficulties with his iron and steel contractor soon required a suspension of operations. Eads had already decided to substitute steel for the traditional cast iron in the arches and thus became the first to introduce the stronger metal into American building techniques. The Carnegie-Kloman Company at first found it impossible to roll pieces with the physical properties that Eads demanded. The earlier cast steel samples had already failed in the testing machines. At this point Eads insisted on the costly and hitherto unused chrome-steel, an innovation which was to have wide implications for structural and mechanical engineering. Equally important was the application of the methods of experimental science to the investigation of the physical properties of the metal. Eads Bridge is the first major structure in the United States in which testing machines, which had been developed over the previous thirty years in Europe, played a vital role in the successful completion of the bridge.

The initial problem solved, construction was resumed in 1868. Eads began with the east, or Illinois, pier, where the maximum depth of bedrock offered the most serious challenge. The pneumatic caisson was a necessity, and thus Eads became the first to introduce its use in the United States, anticipating Roebling by a year. It had been used in Europe since 1849, when Lewis Cubitt and John Wright developed it for the construction of the piers of a span at Rochester, England. Eads built a cylindrical iron-shod caisson of massive timbers heavily reinforced with iron bands. Its

diameter was 75 feet, the working chamber 8 feet deep. Within this huge enclosure the masonry pier was built up, the weight of the masonry forcing the cutting edge into the river bed. The Eads caisson extended continuously up to the water surface, successive rings being added as it sank lower. The caisson for the Illinois pier reached bedrock at 123 feet below water level at the time of construction. Five months of excavation and pumping were required to uncover the foundation rock. Since the top stratum of the bedrock rises steadily from the east to the west bank, the caissons for the center and west piers had to be sunk to a progressively smaller depth, reaching a minimum of 86 feet at the St. Louis pier. The river piers and the masonry arches of the west approach were completed in 1873.

The construction of the steel arches and the wrought iron superstructure was a relatively simple matter after the dangerous work on the piers and required only about one-fifth of the time. In this part of the project Eads introduced another of his important innovations. The tubular arches were erected without falsework by the method of cantilevering them out from the piers to the center of the span. All arches were built out simultaneously from their piers so that the weights of the various cantilevers would balance each other and on completion the horizontal thrusts of adjacent arches would cancel each other. With the arches in place, the spandrel posts and the two decks were erected upon them. The bridge was completed and opened to traffic in 1874. The finished structure between abutments is divided into three spans, the one at the center 520 feet long, the two at the sides 502 feet each, the rise for all of them 45 feet. Eight tubular arches, four for each deck, constitute the primary structure of each span. Wrought-iron spandrel posts and transverse bracing transmit the load of the two decks to the arches. The upper one carries a roadway, the lower a double-track railroad line.

The arches of Eads Bridge are the hingeless or fixed-end type and hence are statically indeterminate structures. It is possible that Chauvenet was familiar with the recent work of French theorists in the solution of problems arising from arches of this kind, and certainly he knew of the many carefully designed wrought iron arches which had been built by French engineers before 1865. The successful attack on problems of indeterminacy was the product of

an international effort in which a great many mathematicians had a hand, among them the great English physicist James Clerk Maxwell. The chief figure in the development of methods of stress analysis for fixed and two-hinged arches was Jacques Antoine Bresse, the first edition of whose *Applied Mechanics* was published at Paris in 1859. But for all the mathematical computations of Eads and Chauvenet, they relied to a great extent—as the engineers always did until the last decade of the century—on empirical approximations and gross overbuilding. Eads calculated that his bridge would be capable of sustaining a total load of 28,972 tons uniformly distributed—about four times the maximum that can be placed upon it—and of withstanding the force of any flood, ice jam, or tornado that the Mississippi Valley could level against it. Now in its ninth decade of active service, the bridge carries a heavy traffic of trucks, busses, automobiles, and the freight trains of the Terminal Railroad of St. Louis.

Sullivan could hardly have chosen a better example to represent the new power of his age. As a work of structural art Eads Bridge remains a classic. In its method of construction and its material, in the testing of full-sized samples of all structural members and connections, in the thoroughness and precision of its technical and formal design, and in the close association of manufacturer and builder, it stands as a superb monument to the building art. It is, moreover, an architectural as well as an engineering achievement. Eads was careful to reduce his masonry elements to the simplest possible form, depending on the rich texture of the granite facing to provide the dignity and sense of restrained power that he was consciously striving for. Nowhere does the masonry extend above the line of the parapet to distract attention from the overall profile, the major parts, and their relation to each other. The tight curve of the arches is the primary visual as well as structural element, and Eads knew that the best he could do was to give full expression to the combination of stability and energy implicit in the form.

The Dixville Bridge posed an entirely different and somewhat less formidable problem. The solution, moreover, belongs strictly to the nineteenth century, the particular truss form employed having been abandoned before the beginning of the twentieth century. It was the decision to use the cantilever principle for a large railway bridge, for which there was only the slightest of

precedents, that excited Sullivan's interest. The occasion in this case was the necessity of bridging the Kentucky River at Dixville, Kentucky, for the Cincinnati Southern Railway. The engineer in charge of the project was L. F. G. Bouscaren (1840-1904), chief engineer of the railroad company and designer of its Ohio River Bridge at Cincinnati, a structure which was built simultaneously with the Dixville Bridge and which contained the longest simple truss span in the world at the time of its erection. There is no question that Bouscaren deserves as much credit as Charles Shaler Smith for the Dixville project, but Sullivan and the rest of posterity have always honored Smith and forgotten the other half of the team.

The chief problem at Dixville was that of erecting the trusses. The Kentucky River gorge at this point is 1,200 feet wide and 275 feet deep. The river has always been subject to flash floods of disastrous proportions, a maximum rise of 40 feet in one day having already been recorded when the two engineers made their preliminary survey. The use of falsework under such conditions was out of the question. Smith originally planned to build a continuous Whipple-Murphy deck truss, 1,125 feet long, extending over three spans of 375 feet each.[5] At this point Bouscaren made the proposal that hinges be introduced into the truss at two points, one at each end of the bridge between the shore and the nearest pier. The use of hinges in a continuous beam or truss was first proposed by the German engineer and theorist Karl Culmann in his *Graphical Statics* (1866). The introduction of hinges and the resulting transformation of the parts of the beam on either side of the support into cantilevers has the consequence that the action of the member more nearly conforms to the theoretical curve of stress distribution, or stress trajectory, as it is sometimes called. The first large cantilever bridge whose design seems clearly to have been influenced by Culmann's theory was Heinrich Gerber's bridge over the Main River at Hassfurt, Germany (1867). The structure excited wide interest and was undoubtedly known to Smith and Bouscaren.

Several other factors, however, led to Bouscaren's decision. In addition to improvement in the efficiency of the truss action, the engineers were concerned to prevent the excessively high stresses which would have occurred in the continuous truss as a consequence of pier settlement. Further, the successful construction of Eads Bridge by the method of cantilevering the arches out from

the abutments and piers suggested not only a similar mode of construction for continuous trusses but also the possibility of using the cantilever as a permanent structural form. By adopting Bouscaren's suggestion the designers turned the bridge into a combination of types which were, in succession from shore to shore, a semi-floating span fixed at the abutment and hinged at the free end, a 75-foot cantilever, a simple truss acting as anchor span to the cantilevers, and so on in reverse order to the opposite shore. The material of the structure throughout was wrought iron. There was, as we noted, little precedent for a bridge of this kind, and Smith and Bouscaren staked their reputations on it. They saw it through to successful completion, but the increasing weight of traffic required that it be replaced in 1911 by a steel bridge built on the same masonry.

Sullivan's intuitive grasp of the meaning of these bridges was perfectly sound. The union of science and technology which made them possible was the creation of men who possessed a rare combination of faculties: they were men who could imagine and think things and who, when they translated the products of imagination into physical fact, did so on a heroic scale. It was difficult not to be impressed, however little one understood the methods of their achievement. Sullivan was profoundly moved, and he knew that he would have to create a building art which could give voice to these powerful feelings and thus evoke them in others.

The Auditorium Building marks the initial step, although what is visible both inside and out at first seems to have little to do with the great achievements of the Age of Iron. Perhaps it is the fact of the building itself, rather than what it says in detail, that heralds a new epoch in architectural form. The exterior walls, as magnificent as they are in their architectonic power, are masonry bearing elements disposed in the long-familiar system of stout piers and arcades. Inside this uniform block, however, is the most extraordinary diversity of internal volumes that one can house in a single structure. The huge theatre, seating 4,000 people, is surrounded by a block of offices on the west and south and by a hotel on the east. Offices, hotel rooms, lobbies, small dining rooms, and other utilitarian facilities are carried on a complete system of framing composed of cast-iron columns and wrought-iron beams. The great vault of the theatre is hung from a series of parallel ellip-

tical trusses which are suspended in turn from horizontal trusses immediately under the roof. The same construction, on a smaller scale, supports the vault of the main dining room. Above the theatre at one end still another type of truss is used to support the ceiling of the rehearsal room. The vaulted enclosures are in no way like the traditional barrel vaults of Roman and medieval building. They are great wide-span cylinders of elliptical or segmental section which were derived from the huge trainsheds of the nineteenth century railway station and thus constitute a metamorphosis of a quasi-monumental utilitarian form into one element of an aesthetic complex. The system of truss framing in the Auditorium grew out of the inventions of the bridge engineers. Under the once brilliant colors and intricate interweaving patterns of Sullivan's ornament, none of this construction is visible, yet the light screens with their plastic detail, and the multiplicity of shapes and volumes could not have been created without the structural means that Adler employed. As a matter of fact, the Auditorium embraces every basic structural technique available to the nineteenth century builder.

The three purely commercial buildings—the Wainwright, the Prudential, and the Carson store—rest on the more advanced structural technique of complete steel framing without masonry bearing members of any kind other than the concrete column footings, but because of the uniformity and relative simplicity of their interior spaces they are much less complex in their construction than the Auditorium. Yet it was precisely here that Sullivan saw his opportunity: now he could take full advantage of the steel frame in the treatment of the elevations, the obvious parts of the building that everyone had to see. What he was trying to articulate in the three buildings was not simply structure and utility, which the bridge engineers had done in their wholly empirical forms, but rather his complex psychological response to the structural techniques that the engineers employed so boldly. The idea underlying the Wainwright and Prudential buildings (Figs. 2 and 3) is clearly summed up in the celebrated passage of the *Autobiography* on the skyscraper. " The lofty steel frame makes a powerful appeal to the architectural imagination where there is any. . . . The appeal and the inspiration lie, of course, in the element of loftiness, in the suggestion of slenderness and aspiration, the soaring quality of

a thing rising from the earth as a unitary utterance, Dionysian in beauty." [6]

The formal character of the Prudential Building (which is a larger and more refined counterpart of the Wainwright and thus may be taken to represent the essential quality of both buildings) is an organic outgrowth of its utilitarian functionalism, but it is in no way confined by it. (Fig. 3) Above an open base, designed chiefly for purposes of display, rises a uniform succession of office floors, identical in function and hence appearance, topped by an attic floor which carries heating returns and elevator machinery and whose external treatment provides a transition to the flat slab that terminates the upward motion of the whole block. Elevator shafts, plumbing, and mechanical utilities are concentrated in an inner core. Sustaining all roof, floor, wall, and wind loads is an interior steel frame covered with fireproof tile sheathing. All this constitutes the empirical answer to utilitarian necessity.

Beyond the empirical form, however, are the wholly aesthetic elements that transform structure into symbolic art. The great bay-wide windows of the base are carefully designed not only to reveal structure but to separate it clearly from all subsidiary elements and thus to give forceful utterance to its potentially dramatic quality. The columns which stand out so clearly are the forerunners of Le Corbusier's *pilotis*, now so common in contemporary building that they have become a cliché. Above the open base appears the single most striking feature, the pronounced upward vertical movement achieved by the closely ranked pier-like bands of which every other one clothes the true structural column, the alternate piers being purely formal additions without bearing function.

The basic theme of this light screen is movement, the dynamic transcendence of space and gravitational thrust, qualities Sullivan long before felt in the " floating " chains and roadway of the Merrimack suspension bridge. In a broader sense the theme suggests the underlying energy of a world of process, of evolutionary growth in living things, or the dynamic of the electric field in physics. The bridge, like the building, is not seen by Sullivan as a static thing but as something which leaps over its natural obstacle and thus becomes a living assertion of man's skill operating through his simultaneous dependence upon and command over nature.

Again Sullivan's intuition led him into the right path, for this is exactly how the bridge behaves. We can sense this directly in the suspension bridge with its wire cables and suspenders: it seems alive, constantly quivering under its changing load. Although we can neither see it nor feel it, exactly the same thing is occurring in the dense and massive members of the big railroad truss as the internal stress continuously adjusts itself to the moving weight that it sustains. It took a century and a half of painstaking scientific inquiry to discover this hidden and vital activity.

The rich and intricate ornament that covers the two office buildings, an ornament created by Sullivan which died with him, offers a much more difficult problem of interpretation. It is so subjective that it is scarcely possible to find objective experiences that might have led to the feelings out of which it grew. In its complex, somewhat abstract naturalism, it appears to symbolize the biologically organic. While Sullivan sometimes allowed his ornament to flow in uncontrolled and undifferentiated profusion over much of the surface, he was generally careful to observe the limits of architectural ornamentation. By spreading it in low relief over whole elevations, and by confining a particular pattern to the surface of a certain kind of structural member—column, or spandrel beam—he was able to distinguish in a striking way the separate structural surfaces. Thus his ornament enhances the major elements of the structure and further heightens the vivid sense of movement. It also seems to suggest the diversity underlying the unitary organic statement.

In the Carson Pirie Scott Store Sullivan turned to an entirely different kind of expression, one derived from the dominant mode of the work of the Chicago school. (Fig. 4) Where he used the close vertical pattern in the older buildings, in the department store he opened the main elevations into great cellular screens which exactly express the neutral steel cage behind them. The form was dictated initially by the requirement for maximum natural light in the store, but again, in many subtle ways, he translated the practical functionalism into art. If the theme of the Wainwright and the Prudential is movement, that of the Carson store is power. Here the elaborate interplay of tension and compression, of thrust and counterthrust in the bridge truss is given a heightened and dramatic statement by means so delicate as almost to escape notice–

the careful calculation of the depth of the window reveals and the breadth of the terra-cotta envelope on the columns and spandrels, the narrow band of ornament that enframes the window, the even narrower band that extends continuously along each sill and lintel line to give the whole façade a tense, subdued horizontality. The base in its sheath of ornament is an exact reversal of that of the office buildings. In the Carson store it is a weightless screen, glass and opaque covering (cast iron) forming one unbroken plane, making the cellular wall above literally seem to float free of the earth below it.

In the last analysis Sullivan's civic architecture is a celebration of technique, as is most of the contemporary architecture of which he was the foremost pioneer. But Sullivan had carried the expression far beyond the rather sterile geometry that characterizes most building today. If his work seems limited beside the vastly richer symbolism of medieval and baroque architecture, we may at least say that he was responding to the one coherent order that was discernible in the contradictory currents of nineteenth and twentieth century culture. In the absence of a cosmos in which man was conceived to be the central figure, the scientific technology on which building increasingly depended became the one sure basis of architectural and civic art. It is Sullivan's achievement to have understood how this basis could be transmuted into an effective and valid artistic statement.

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[2] *The Autobiography of an Idea* (New York, 1926), pp. 82-85. By permission of the American Institute of Architects.

[3] *Ibid.*, pp. 246-48.

[4] *Ibid.*, p. 248.

[5] The Whipple-Murphy truss was a variation on the form patented by Squire Whipple in 1847. Its distinguishing characteristic is the fact that the diagonal members of the web slope in one direction in any one half of the truss and cross two panels formed by the posts, instead of the usual one. A continuous truss is one that is carried on intermediate supports as well as those at the ends, that is, it extends continuously over more than two supports. In a deck-truss bridge the deck, or track level, is located at the level of the top chord of the truss.

[6] *The Autobiography of an Idea*, pp. 313-314.

Personal Notes

AN APPRECIATION OF WILLIAM FIELDING OGBURN

OTIS DUDLEY DUNCAN*

WILLIAM FIELDING OGBURN, shortly after being elected the first president of the Society for the History of Technology, died on April 27, 1959, following a brief illness. His loss was felt not only by the new Society, which he was instrumental in founding, but also by a large segment of the world of learning, for at the age of seventy-two Ogburn continued to be active in many fields of research as he had been throughout his long and distinguished career.

Ogburn's contribution to knowledge concerning technology and social change can best be understood in the context of his work as a whole. To begin with, he was not a specialist, although he often commented on the necessity of intellectual specialization in an age of accelerating increase in the volume of knowledge, and the great range of his interests can only be indicated briefly. His early research concerned the history of social reform legislation and determinants of voting behavior—topics not unrelated to his political sympathies. Two years in government service around the end of World War I led to notable contributions on measurement of the cost of living and analysis of consumer expenditures. Somewhat earlier, he had developed the strong interest in psychoanalysis which he was to maintain throughout his life and to use effectively in studies on the problem of bias in science. A pioneer in the application of statistical methods to sociological, economic, and

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political problems, he served as editor of the *Journal of the American Statistical Association* from 1920 to 1926 and later as president of that organization. His many investigations in social statistics led to noteworthy studies on marriage and the family, demography, social concomitants of business fluctuations, and variation in the social characteristics of cities.

At a relatively early age Ogburn had drawn up for himself a list of what he called the "great questions," as, for example: How does an animal with the original nature of a cave man adapt to life in the modern city? Do great men influence the course of change independently of social forces? Can human happiness be increased by improving child training practices? A number of such issues were brought into juxtaposition in the small volume that has become a sociological classic, *Social Change with Respect to Culture and Original Nature* (1922, reissued in 1950 with a supplementary chapter, "Social Evolution, Re-considered"). Much of Ogburn's work in the following years consisted of variations and elaborations on themes stated in this book.

Many sociologists feel that Ogburn's principal impact on social science derived from his tireless insistence on verification and the need to replace literary and speculative approaches by systematic research using quantitative data and statistical techniques. Yet, particularly where his own major substantive interest—social change—was involved, he never became preoccupied with techniques for their own sake. In a personal letter of July 14, 1958, he wrote: "My interest in social change, looking at the matter personally and remembering the adage *de gustibus non disputandum est*, has been largely on significance and meaning rather than on methodology. I have a tendency to try to see what I call 'big ideas' or develop a sense of the significant." In this respect, as in many others, he displayed more than one facet of a versatile mind and a complex character. The emphasis on science as an accumulation of factual knowledge with high reliability, coupled with a virtual disdain for what he called "scholarship" and "intellectualism," may be seen in his own statistical studies of social trends, the series of annual symposia on "Recent Social Changes" which he edited for the *American Journal of Sociology* (1928-35, 1942), and the monumental *Recent Social Trends* (1933), a collective undertaking of which he was research director. In contrast, in much of *Social*

Change, as well as such noteworthy articles as "The Great Man Versus Social Forces" (1926),[1] "Stationary and Changing Societies" (1936),[2] "Inventions, Population and History" (1942),[3] and "Sociology and the Atom" (1946),[4] there is manifest a willingness to set forth broad, synthetic generalizations, to use deductive argument where data are scanty, and to engage in bold, albeit disciplined, speculation. Indeed, it is not fanciful to discern in much of Ogburn's writing a fortunate tension between the requirements of science as he understood them and his impatience to formulate powerful explanatory principles.

At the risk of distortion through oversimplification, we can summarize Ogburn's contributions to the study of technology and social change under five major headings.

The theory of (1) *cultural evolution* was worked out in the years following 1914 when Ogburn was heavily influenced by the anthropologists Boas, Lowie, and Kroeber. While he had previously been impressed with the possibilities of eugenics, he now concluded that the mainsprings of social change are to be found in superorganic, not organic evolution. Taking technological development as a prototype, he identified invention as the basic source of social change. Granting that inventions often are associated with the exercise of superior mental ability, he supposed that mental ability is a nearly constant factor. While demand for invention channels inventive effort, the more important role of demand lies in determining uses made of inventions. More fundamental than either of these is the accumulation of previous inventions–the culture base–since inventions are primarily recombinations of existing culture elements or modifications of them. There is a certain inevitability about inventions: they come forth when the accumulated culture base is adequate, as is shown by the frequency of simultaneous, independent inventions. The accumulation tends to be exponential, because the number of possible new combinations of culture elements increases with the size of the culture base. Diffusion of culture–the spread of inventions from one area to another–hastens cultural evolution by making the total culture base more widely available. Finally, inventions in one part of culture instigate inventions in others. The parts of culture are interrelated, and changes in one part call forth adaptive changes in the parts related to it. Quite often, at least in modern times, the

initial inventions are technological, and the adaptive changes are in institutions and social structure. "Social inventions," then, may be seen as adjustments to change in material culture.

These adjustments, however, are seldom instantaneous. The delay is the well-known (2) *cultural lag*, a period of disequilibrium, imbalance, or disturbance of harmonious relationship between the parts of culture. What we call "social problems" are generally manifestations of the maladustment resulting from cultural lag. Although such maladjustment sets in motion forces seeking a new equilibrium, with rapid, continual technological and scientific changes it is to be expected that new lags will appear as old ones are eliminated.

Within this general framework, Ogburn devoted much study to specific (3) *social effects of inventions*. As a scheme of analysis it is postulated that effects are first evident in applications and habits of use of inventions. But the new habits entail derivative effects, or other changes linked in a chain of causation. Derivative changes ramify widely—Ogburn enjoyed speculation about the linkage between the invention of the tin can and the decline of the birth rate—though with successively diminishing influence. Working from cause to effect, he examined major inventions and enumerated uses and derivative effects in a systematic and exhaustive fashion. This is the plan followed, for example, in his *Social Effects of Aviation* (1946) and in the study of radio in *Recent Social Trends*. Inverting the procedure, a certain social institution would be selected for scrutiny and a search made for inventions and derivative influences thereof impinging upon it. Research on city patterns, governmental functions, and the family was prosecuted in this fashion, most notably in *Technology and the Changing Family* (with M. F. Nimkoff, 1955) and *Technology and International Relations* (with others, 1949).

Closely related to the foregoing was a theme that claimed much of Ogburn's attention in recent years, the impact of technology on the (4) *standard of living*. Using correlation methods he sought to show by statistics that international variation in per capita income was more fully explained by differences in available technological equipment than by variation in natural resources, the Malthusian factor of population density, or private versus public ownership of production facilities.[5] He also attempted to demonstrate that a

major fraction of the rise in the standard of living in this country since 1900 is explained by technological development.[6] Assuming continuation of such development and neglecting catastrophic changes, Ogburn foresaw a doubling of average family income (in constant dollars) between 1950 and the end of the century.[7]

I have referred to the voluminous research on (5) *measurement of social trends* carried out or directed by Ogburn. Here empiricism came to the fore, inasmuch as all changes registered in statistics or otherwise supported by good evidence were eligible for consideration, although there was some selection based on criteria of importance and topical interest. Ogburn pointed out that pioneering work by individual research workers in this area was needed to lay the basis for later routine collection and publication of government statistics. (His own contribution to the enlargement and improvement of government statistical activities was no mean one.) Two points of theory were emphasized in the research on social trends. Trends (i. e., the secular movements, not the annual fluctuations of time series) are usually persistent, rarely changing direction drastically or suddenly. Even a major war may have surprisingly little influence on their course. Second, this stability in the pattern of change results, among other things, from the fact that trends are initiated and supported by a multiplicity of converging influences—technological developments, of course, are of first importance in many instances. The same consideration argues that planned redirection of change is likely to be difficult. Cautious optimism about the success of planning is warranted if efforts are directed toward foreseeing the future course of social trends and the effects of recent and anticipated inventions and toward the establishment of control mechanisms to facilitate the inevitable adjustment to change.

Although Ogburn made a sharp distinction between the role of the scientist and the roles of citizen and counselor to policy makers, it is evident that the kind of science he urged us to build has great significance for the intelligent exercise of the citizen's duties.

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Book Reviews

Khami Ruins. Report on Excavations Undertaken for the Commission for the Preservation of Natural and Historical Monuments and Relics, Southern Rhodesia. 1947-1955. By K. R. Robinson, with reports by G. Bond and E. Voce. Cambridge University Press. 1959. Pp. xvi, 179. Index. 28 plates. 50 figures. Colored frontispiece. $7.50.

On both sides of the Khami River, thirteen miles from Bulawayo, Southern Rhodesia, there is a scatter of low rocky hills formed by outcrops of granite. These *kopjes* have for untold centuries provided vantage points and sheltered areas for the open camps and kraals of a succession of hunters, pastoralists, and farmers. The Khami Ruins testify to the last of these occupations, one which terminated just prior to intensive European contacts in the early nineteenth century.

The Khami River dwellers of this late prehistoric period kept livestock and practiced agriculture to the limited extent permitted by the thin, sandy soil of the region. They were excellent potters, producing a variety of forms with sophisticated designs. They possessed objects of iron, copper, bronze, and gold, although it is uncertain whether they mined or smelted the ores of these metals. They lived on and around the *kopjes* and left unmistakable evidence of their prolonged occupancy in the remains of numerous huts on the low lands as well as in fifteen or more extensive habitation sites on hilltops. The most conspicuous features of the latter are their massive foundations which consist of leveled summits shored up by revetments of dressed stone laid in ornamental courses. Free standing walls also occur in association with the huts built on the summit platforms.

The Khami Ruins and others like them in Southern Rhodesia have long been known to the white residents of the area. They have attracted the attention of gold seekers and have given rise to many speculations, some quite imaginative, ever since the end of the last century. Scientific reports based on superficial examinations have also appeared sporadically since 1900. In 1947 K. R. Robinson began a program of systematic excavation, a laborious undertaking that was still continuing at the time of the writing of the report which is the subject of this review. Due to the necessity of preserving the ruins (now a national monument) as much as possible, excavation had to be restricted; but the author believes that archaeological evidence that

might be forthcoming in the future will not significantly alter the findings to date.

The simplest structures that have been examined are the lowland circular huts with fairly thin walls of clay-plastered wattle and a thatched roof. Presumably these were the dwellings of commoners. The same materials and methods of construction were employed in building the larger huts on hills, but their walls were massive and formed parts of irregular enclosures bounded on other sides by walls of stone blocks or clay. In some instances these compounds were elaborated by associated hut areas and by chambers and passageways constructed in part of stone. It is supposed that these complexes provided dwellings, stock pens, and ceremonial retreats for the chiefs and their advisors. Whether simple or complex, all structural units rested on raised platforms of a compacted clay which produced a weather resistent flooring but necessitated a drainage system. The transfer of the hut platform to hilltops accounts for the imposing stone fills and embankments on those locations. The custom of re-using abandoned hilltops sites accounts for another of their striking features, namely, the adaptation of parts of earlier structures to suit the needs of new occupants. In some instances new retaining walls were built on the remnants of older ones; in others they were recessed so that a terrace was created.

Robinson found that a closely related assemblage of artifacts known as Leopard's Kopje Culture underlay Khami remains in one of his excavations. It therefore antedates Khami, in part, at least. These earlier materials included distinctive types of pottery and glass beads, both of which appear to have affinities with finds at Mapungubwe and Bambandyanalo on the Limpopo River. Their possessors lived in clay huts clustered in small groups around the bases of *kopjes*. They appear to have been the first metallurgists, stock breeders, potters, and agriculturists in the region, for a test trench revealed that the floors of their habitations rested on a sterile layer of sand, and that in turn overlay a stratum of gravel containing cores and flakes identified as Middle Stone Age products. Late Stone Age artifacts were not represented in this stratigraphic section, although microliths have been found at a nearby site.

As for dating, Robinson makes this estimate: "On the available evidence I regard 1700 as the earliest probable date for the first wall-building on the Hill Ruin [the most complex site at Khami]. With regard to the Leopard's Kopje Culture I think it may cover a long period, because it was associated with gold mining, and the latter occupation, as pointed out by Summers (1950; see also Mennel and Summers, 1955, p. 722), began about A. D. 900. I believe that this culture was practised by the bulk of the people in Matabeleland and south of this area during the greatest expansion of the Empire of Munumutapa." On connections with remains elsewhere he writes: "That

all our Southern Rhodesian Ruin Culture had a common starting point, which may have been Zimbabwe, appears to be a reasonable supposition. With the origin of the Zimbabwe Culture we are not here concerned, but the evidence would appear to indicate clearly that the type of culture responsible for the earliest buildings of dressed and coursed stone at Zimbabwe was, in all essentials, indistinguishable from that responsible for ruins such as Dhlo Dhlo and Khami."

This places the builders of Khami Ruins unambiguously in Schofield's Mambo Period and thus relates them to existing Bantu tribes. In his 1941 "Survey of the Recent Prehistory of Southern Rhodesia" (*South African Journal of Science*, XXXVIII [1942], 81-111), Schofield divided Bantu occupancy of the region just prior to extensive European contacts into three periods. During the first period, antedating 1400 A. D. and termed Early Rhodesian, the area was held by a population ancestral to the Sotho and related tribes. The Monomotapa Period, lasting from 1400 to 1700, was inaugurated by a movement of the Shona people southward from the Zambesi in a maneuver that forced their predecessors to the east and southwest. The Mambo Period opened with the conquests of a Roswi chief at the end of the seventeenth century and closed with the destruction of the dynasty that he founded by the Nguni invasions of 1830. Thus, "it was to some ascendant and now disintegrated tribal unit, of which BaRoswi and BaVenda are two of the offspring, that the 'ruin builders' belonged." (G. Caton-Thompson. *The Zimbabwe Culture* [1931], p. 194).

Robinson's report is clearly and simply written. In addition to presenting the details of his excavations he gives a tabular inventory of all objects recovered and descriptive appendices on their several categories, such as beads, pottery, and metal objects. There are numerous sketches and line drawings of artifacts and excavation profiles, all expertly exhibited. The photographic reproductions and typography add distinction to this substantial contribution to South African archaeology.

H. G. Barnett *

The Atlantic Cable. By Bern Dibner. Publication No. 16, Burndy Library in the History of Science Inc., Norwalk, Conn., The Burndy Library, 1958. Pp. 96. Illustrated.

Bern Dibner has written a lucid chronological history of the laying of the Atlantic Cable. He covers the early experiments of Morse in New York Harbor in 1842; Ezra Cornell's laying of a line across the Hudson River in 1845; the five actual attempts at laying the cable; and

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the eventual success in completing two telegraph circuits connecting Newfoundland and Ireland in 1866. Written a century after the initial expedition set forth in 1857, distance in time permits the placing in perspective of all phases of accomplishment of a great engineering achievement.

Cyrus Field was, in the words of Sir William Thomson (later Lord Kelvin), the "originator and mainspring" of the project, which was regarded as foolhardy in many quarters. At the outset in 1854, Field realized that many electrical, mechanical, oceanographical, and nautical problems would have to be solved. Having sought and obtained encouragement of specialists in each of these areas, he was able to raise the necessary capital to finance the design, manufacture, transportation, and laying of the submarine telegraph cable. Field did not foresee, however, that the enterprise would take twelve years and forty long, hazardous trans-Atlantic crossings (the first by sailing vessel); that it would touch the fields of science, politics, finance, and geography; and that it would cost $12,000,000.

This book makes clear the roles of Field and Morse and Thomson, of the ships' captains and the financial backers, and of all those who played a part in the courageous undertaking. Brief biographical footnotes keep the reader informed about the principals as the saga unfolds. The author is a tireless researcher, and his work is carefully documented. It is also immensely readable and suspenseful.

Technical difficulties and incredible hardships plagued the men who sought to lay the cable. Time after time, their hopes were gradually raised, then dashed suddenly by a heartbreaking mishap. Yet each time, they made new plans and began again. Every failure seems almost to have been a necessary step toward eventual success. The reader shares a sense of triumph when he comes upon these words in Field's message from Trinity Bay to New York on July 27, 1866: "Thank God, the cable is laid, and is in perfect working order."

But the story does not end there. Within five days, the expedition had turned back into the Atlantic to attempt to retrieve cable lost the previous year, which lay 600 miles away in two and a half miles of water. Three weeks later, the cable was brought to the surface for the first time, only to part and splash back into the ocean. Thirty attempts were to be made before the cable was successfully raised on August 31st. It was tested and spliced to another length, which was laid on the return voyage to Trinity Bay. Thus, the second Atlantic telegraph circuit was completed.

The monograph is concise, almost synoptic, and condenses into 96 pages material which easily could be expanded into a full-length book. Experiences in the Newfoundland wilderness could alone fill a chapter.

Mr. Dibner's pages are generously sprinkled with illustrations of historical and engineering interest, including a photograph attributed to Daguerre, Paris, 1845. There are reproductions of etchings, paint-

ings, drawings, and documents. Most enlightening of all is a two-color map and chart insert which shows simply and clearly the chronology of expeditions and the locations of their terminations.

This is an irresistible and inspiring story of man's vision, perseverance, and triumph over the forces of nature; over human nature, too. Those who are familiar with the electrical engineering milestone it describes will find in the book a neat summation. Those who have yet to become acquainted with the details will find it rewarding reading indeed. Incidentally, the book should be required reading for America's young people. They would find it surprisingly palatable fare.

The Atlantic Cable, as presented by Bern Dibner, leaves one with the conviction that any problem which a number of informed and dedicated men working together believe can be solved, inevitably will be. By drawing a simple parallel, one sees that man's exploration of space is certain of accomplishment.

L. F. HICKERNELL *

American Automobile Manufacturers: The First Forty Years. By John B. Rae. Philadelphia and New York: Chilton Company; 1959. Pp. xii, 223. $6.00.

This careful, scholarly history is an important contribution to the literature on the American automobile industry. Its title describes exactly the coverage of the work—the subtitle on the dust cover, *A History of the Automobile Industry*, which is not on the title page, is too ambitious. The work does not pretend to be a complete history of the industry and its impact, but is the story of the manufacturers themselves. As such it is a good example of what has come to be called "entrepreneurial history." It is a fascinating story of very diverse beginnings, of a Spencerian struggle for existence (never was social Darwinism more graphically illustrated!), of the gradual emergence of the present pattern of a small number of large producers, and of a truly extraordinary group of personalities—the bewhiskered Popes of Hartford, thin-lipped Henry Ford, and the utterly irrepressible William C. Durant. The detailed history is carried only through the 1920's —one hopes that some day we may have the next thirty years from the same author, though this is a very different kind of story.

A theorist like this reviewer naturally looks not only at the historian's careful survey of the facts as revealed by the documents but at the material as a possible source of broader generalizations, which the historian quite properly eschews. Entrepreneurship is one of the great mysteries of economic life, and the absence of any adequate theory of

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entrepreneurship is the greatest weakness of the theory of economic development. A work like this is a rich mine of crude information; one emerges from it, however, with not much in the way of glamorous generalizations and with an almost oppressive sense of the variety and complexity of the entrepreneurial character. Two great unanswered questions spring to mind: First, is there any common quality of these entrepreneurs which distinguishes them from ordinary men, and if so, where in their life experiences—or maybe genetic constitution—does this common quality come from? The second question is crucial to the theory of economic development. It is the question of the nature of the supply of entrepreneurship. Is this supply highly elastic, so that all that is needed for a great outburst of development is demand—that is, opportunity? Or is it inelastic, so that we have to explain these outbursts of development by shifts in supply—some social conjuncture which gives rise to a whole new crop of entrepreneurs? Is it only opportunity that needs to knock, and a whole host of eager venturers will answer, in which case we need not worry much about entrepreneurship itself? Or do we have occasions when opportunity knocks and nobody answers, when the tone of the society is slack, sluggish, and unadventurous? In the first case the problem is how to provide opportunity, in the second how to provide response. There is no general answer to this question, but the present work certainly indicates that in the peculiar conditions of the end of the nineteenth century in America, the supply of entrepreneurship was highly elastic. One gets the impression of a society pullulating with entrepreneurs of all kinds and from diverse sources, where the knock of opportunity produced a frantic rush to open the door in which a good many casualties were suffered!

One general impression which emerges from the story is a renewed sense of the sheer ingenuity and vitality of American society, not only in mechanical but in social inventions. The response of the automobile industry to the curious problem of the Selden patent is one such story. I confess I was even more impressed by the story of the Peerless Motor Car Company of Cleveland, which moved from clothes wringers to bicycles to automobiles to Carling's Ale—a record of product adaptability surely unequalled! It is curious how economists have neglected the problem of the choice of product, when this is perhaps the most crucial problem of the firm from the point of view of survival.

This work is a historian's history of high quality, rich in content, cautious in generalization, and an important contribution to a fascinating story.

K. E. Boulding *

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Organizational Notes

THE SOCIETY FOR THE HISTORY OF TECHNOLOGY

A BRIEF HISTORY

The "pre-history" of the Society for the History of Technology begins with the Humanistic-Social Research Project (1953-1955) of the American Society for Engineering Education. Under a grant from the Carnegie Corporation of New York, the Humanistic-Social Division of the ASEE undertook a survey of the Humanistic-Social stem in engineering curricula and issued a report (published under the title *General Education in Engineering* [1956]) which pointed out that the study of the history of technology was "of special interest and importance for engineering education" and recommended that it be "encouraged," while at the same time guarding against possible overemphasis and distortion.

A special committee, headed by Dr. Melvin Kranzberg, was appointed to implement this aspect of the Humanistic-Social Research Project's report; this committee soon discovered that the history of technology was being taught only sporadically and that there was no organization or publication specifically devoted to its study. Despite this lack of a systematic approach, it was evident that there was tremendous interest in the development of technology, not only among engineering educators and historians, but among all academic disciplines. Indeed, the demand for the systematic, scholarly study of this field was found to extend far beyond academic circles.

With encouragement from many individuals, most notably Drs. Carl W. Condit and John B. Rae, Professor Kranzberg formed the Advisory Committee for Technology and Society, which included academicians, engineers, and industrialists who had evinced interest in the history of technology. A preliminary meeting at Cornell University in June 1957 discussed the areas of study comprehended within the field of technology and its relations with society and culture. These areas of study were circulated among the members of the Advisory Committee, as were various proposals for promoting the study of the development of technology.

In January 1958, Case Institute of Technology sponsored a meeting of the Advisory Committee for Technology and Society in Cleveland, Ohio. At that time it was decided to establish The Society for the History of Technology, which would conduct programs, publish a scholarly journal, and take any other steps necessary to encourage the study of the development of technology and its relations with society

and culture. The Society for the History of Technology was incorporated in May 1958, as a non-profit educational organization, in accordance with the laws of the State of Ohio, and the constitution of the Society was adopted at a meeting at the University of California (Berkeley) in June of that year. At the same time the first program of the Society was held in conjunction with the Humanistic-Social Division of the American Society for Engineering Education.

The first annual meeting, including the election of permanent officers, took place at the Smithsonian Institution in Washington, D. C. in December 1958. There the Society conducted joint programs with the American Historical Association and Section L of the American Association for the Advancement of Science.

In April 1959 the Society suffered a severe loss with the death of its first president, Dr. William Fielding Ogburn. However, the Society was so well established by that time that it was able to continue its growth. These have resulted in scholarly programs of a high order and the publication of a quarterly journal, *Technology and Culture*.

The first program consisted of joint sessions with the Humanistic-Social Division of the American Society for Engineering Education at the University of California (Berkeley) on June 16-17, 1958, as follows:

June 16, 1958

Chairman: Lynn White, Jr., President, Mills College.

"The Role of the Technical Museum in Engineering Education," Robert P. Multhauf, Head Curator, Science and Technology, Smithsonian Institution.

"Engineering Concepts in the Development of Thermodynamics," Thomas S. Kuhn, Assistant Professor of the History of Science, University of California (Berkeley).

June 17, 1958

Chairman: Stuart W. Chapman, Professor of Humanistic-Social Studies and Executive Officer, College of Engineering, University of Washington.

"Relations of Science, Technology, and Art in Nineteenth Century Building," Carl W. Condit, Associate Professor of History, Northwestern University.

"Technology and Cultural Values in American History," Edward Lurie, Instructor in History, University of Michigan.

The second program of the Society was held in Washington, D. C. on December 29-30, 1958, as follows:

December 29, 1958—Joint Session with the American Historical Association.

Theme: Technology and Culture.

Chairman: John U. Nef, University of Chicago.

"India, Tibet, and Malaya as Sources of Medieval Technology," Lynn White, Jr., University of California, Los Angeles.

"Impact of Technological Innovation on Social and Cultural Values in Modern India," Robert I. Crane, University of Michigan.

Comment: Arthur W. Hummel, Library of Congress.

December 30, 1958—Joint Session with Section L of the American Association for the advancement of Science and the History of Science Society.

Theme: History of Technology in America.

Chairman: Carl W. Condit, Northwestern University.

"John Ericsson and the Age of Caloric," Eugene S. Ferguson, Smithsonian Institution.

"Some Technological Views of American History," John B. Rae, Massachusetts Institute of Technology.

"The Lessons from the Saugus Ironworks Restoration," E. Neal Hartley, Massachusetts Institute of Technology.

For its December, 1959 meeting in Chicago, the Society scheduled joint programs with the American Historical Association and the American Association for the Advancement of Science. A full report on these programs will appear in the next issue of *Technology and Culture*.